GTE-ERS
TECHNICAL LIBRARY
02247

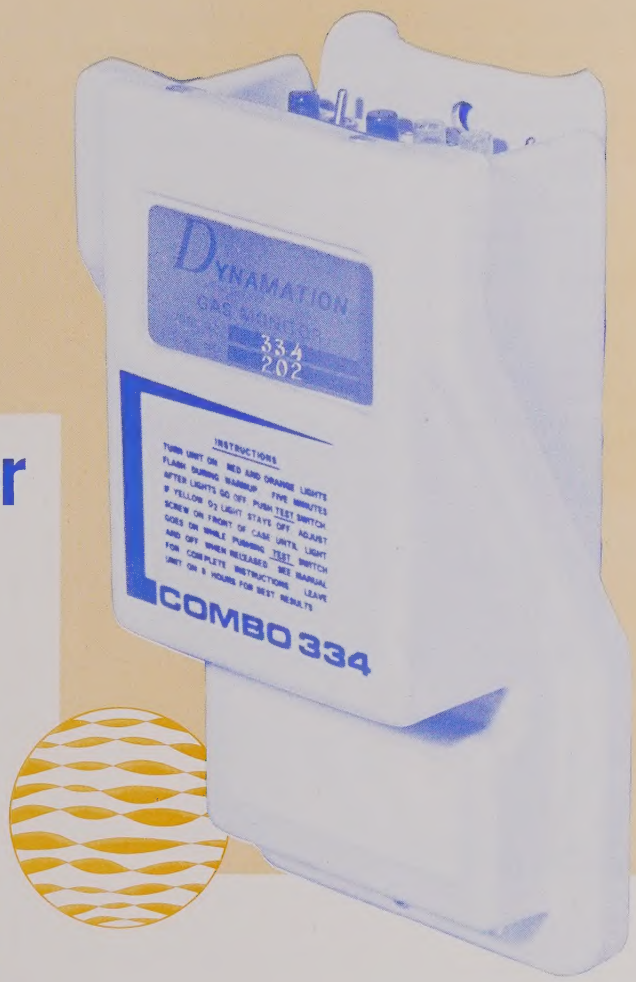
DYNAMATION 035

Combo Series

Combination Gas Monitoring Instrument No. 334 for Oxygen, Combustible and Toxic Gases.

APPLICATIONS

Waste Treatment	Sewers and Manholes
Fire Departments	Surveys
Shipping	Compartments and Holds
Utilities	Manholes and Vaults
Construction	Tunnels
Chemical	Tanks
Refineries	Process Areas
Mining	Underground
Petroleum	Gas Fields
Inspection	All Enclosed Areas



Combo 334 Gas Monitor

Alarms to Dangerous Gases in Confined Areas

The COMBO 334 will continuously protect workers in underground or confined areas against accumulations of Combustible, a range of Toxic gases and exposure to Oxygen Deficient atmospheres. Belt warn, the lightweight COMBO stays with the worker and warns of pockets of gas that might be missed by aspiration testing at the entrance. Audible alarms and visual indicating lights warn and distinguish between combustible, toxic or oxygen deficient conditions.

A beaded platinum sensor detects Combustible gases while a metal oxide semiconductor toxic sensor responds to Hydrogen Sulfide, Carbon Monoxide, Organic Vapors and other oxidizable gases. These simple to replace, plug in sensors last up to three years in normal use.

A chemical, temperature compensated cell measures O_2 levels and has up to 1½ years of life before replacement. Easily calibrated without special tools or gases, this O_2 cell will operate at temperatures as low as 0° F. To replace an expired cell, simply remove and plug a new cell into the circuit board connector.

The COMBO solid state electronics are packaged in a high impact plastic case. The hinged case cover is secured by a positive threaded latching fastener and is gasket sealed. The rechargeable battery pack can easily be changed in the field with a fully charged battery pack, thus extending the continuous operating time indefinitely. Sensors are protected by a porous, breathable plastic screen which keeps water and dirt from entering the unit.

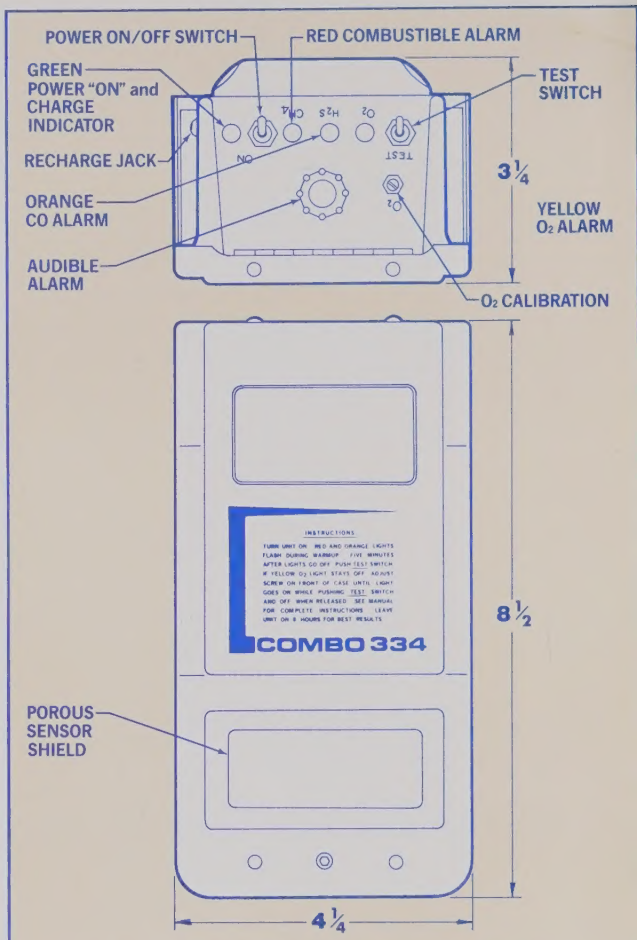
To operate, turn the unit on and note that the green LED (Light Emitting Diode) is on. This indicates battery power is adequate. Three other LED alarm lights are positioned on the top of the instrument to warn of hostile conditions; Red - combustible, Yellow - oxygen deficiency and Orange - toxic gases. Allow a few minutes for the instrument to warm up, during which time the red and orange lights will blink. When the lights stop flashing the sensors are stabilized at the proper operating temperature and the unit is ready for use. A test switch is also provided to check audible alarms and O_2 cell calibration. No aspiration is required because natural diffusion of the heated sensors supplies sufficient air flow. When the battery pack needs recharging, the green LED shuts off and a low battery alarm sounds for 15 minutes, after which the instrument automatically shuts off, protecting the battery from being totally drained of power. Simple calibration is done in less than ten minutes with Dynamation's calibration kit No. 7707-011. The combination Combustible/Toxic test gas is exposed to the sensors for one minute so that respective alarm levels may be adjusted to trigger.

Features

- Continuously Monitors Air for Combustible, Toxic Gases and Oxygen Deficiency
- Audible Alarm Sounds in Hostile Atmospheres
- Visual Colored Light Alarms Define Unsafe Combustible, Toxic or Oxygen Deficient Conditions
- More than Eight Hours Continuous Operation before Recharging is Required
- Audible Alarm Warns of Low Power Condition
- Controlled Warm up Cycle
- Rechargeable Battery Pack is Replaceable for Extended Usage
- Easy Calibration

Specifications

Sensors	
Combustible	Plug in, Platinum Beaded
Oxygen	Plug in, Chemical Cell
Toxic	Plug in, Metal Oxide Semiconductor
Calibration	
Combustible	Red Light, 20% LEL Methane
Oxygen Level	Yellow Light, Less than 19.5% V
Toxic	Orange Light, 100 ppm
Gases Detected	
Combustible	Combustible Hydrocarbons, Gases and Vapors
Oxygen	Oxygen Level
Toxic	CO, H_2S, MEK, Benzene, Trichloroethylene, etc.
Response Time	
Combustible	90% in 5 sec. to 20% Natural Gas
Oxygen	90% in 30 sec.
Toxic	90% in 90 sec. to 100 ppm CO
Controls	Power ON/OFF and TEST switches
Warm Up Time	Approx. 5 minutes
Enclosure	High Impact Plastic Case
Batteries	NiCad Rechargeable
Continuous Operation	9 Hours
Temperature Range	0° to 100° F
Dimensions	8"L x 4"W x 2¾"D
Weight	30 ounces



COMBO 334 GAS MONITOR

Accessories

Calibration Kit for calibrating unit with Carbon Monoxide and Methane Gases. Stock No. 7707-011

Rechargeable Battery Pack, six NiCad batteries in a plastic snap in case. Stock No. 4002-001

Battery Charger, 12v DC for use in truck cigarette lighter receptacle. Stock No. 4001-003

Aspirator Attachment with Manhole Wand for drawing sample gas into unit. Stock No. 7707-006

Porous Plastic Screens (Package of 10) Stock No. 2601-011

DISTRIBUTED BY

dynamation, inc.
3784 plaza drive
ann arbor, michigan 48104
(313) 769-0573

Bulletin No. 8210-334-A
Printed in USA

©Dynamation, Inc. 1985

INSTRUCTION MANUAL

COMBO 333 and COMBO 334

The Dynamation Combo is an essential safety device for workers entering manholes and other confined spaces where a potential of combustible, oxygen deficienty and/or toxic gases exist. Your Combo operated as described herein should give years of trouble free operation.

NOTE: ALL GAS DETECTION SENSORS HAVE A FINITE LIFE EXPECTANCY. ALWAYS CHECK YOUR INSTRUMENT FOR PROPER OPERATION BEFORE USING.

MODEL COMBO 333

Gas	Alarm Light	Standard Factory Alarm Levels	Sensor Life Expectancy
H_2S	Orange	10PPM	2 to 3 yrs.
O_2	Yellow	19.5% Vol.	1 to 1 1/2 yrs.
CH_4	Red	20% LEL	2 to 3 yrs.

MODEL COMBO 334

Gas	Alarm Light	Standard Fectory Alarm Levels	Sensor Life Expectancy
CO	Orange	100PPM	2 to 3 yrs.
O_2	Yellow	19.5% Vol.	1 to 1/2 yrs.
CH_4	Red	20% LEL	2 to 3 yrs.

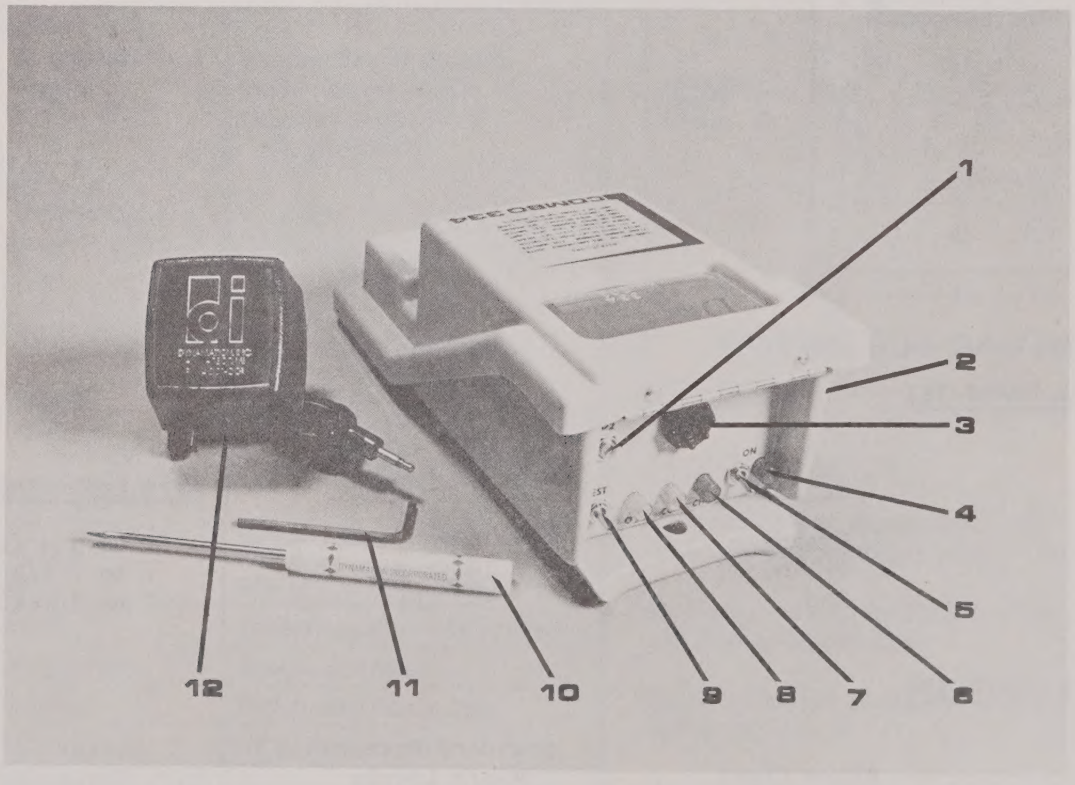
DESCRIPTION

GENERAL

This manual is for Combo models 333 and 334. Both models were incorporated in one manual because they can be easily changed from one model to another. The difference between the two models is the toxic gas sensor. In the Combo 333, the sensor is specific to detecting only hydrogen sulfide compared with the Combo 334 sensor which detects most oxidizable gases such as CO, hydrogen sulfide, benzene, trichlorethylene, etc. Be careful that the instructions discussed pertain to your model instrument - especially gases detected and unit's calibration.

The Dynamation Combo is an instrument used as a life protection device and should not be used until this operation and maintenance manual has been thoroughly read and understood and until all routine checks and tests have been carried out as detailed.

IDENTIFICATION



1. O_2 Calibration Adjustment
2. Charger Jack
3. Horn
4. Power and Battery Charge Light
5. Power OFF/ON Switch
6. Combustible Alarm Light (Red)
7. Toxic Alarm Light (Amber)
8. O_2 Deficiency Alarm Light (Yellow)
9. Test Switch
10. Screw Driver
11. Allen Wrench
12. Charger

GUIDE FOR TROUBLE FREE USE

The Dynamation Combo is designed to give years of trouble-free service when operated according to instructions. The instrument is, however, a sophisticated life protection device performing several functions with little margin for error and must be treated accordingly. Do not expect to be able to leave the unit idle for weeks or months at a time and have it perform as needed on a moments notice.

While ignoring the unit for extended periods of time is the best way to invite trouble, it does not require much effort to keep your unit in excellent running order. You can avoid further difficulties by following the guidelines in the chart below.

1) Assign responsibility of instrument to one individual or department.
2) Inspect and calibrate on a 30 day basis.
3) Run for full 6-8 hour cycles.
4) Keep batteries on charger between run cycles at temperature of about 70°F.
5) Store in clean environment at temperatures around 70°F.
6) DO NOT BLOW SMOKE, SQUIRT BUTANE, ETC. ON THE INSTRUMENT.

NOTE: The Combo should be put through a full 14-16 hour recharge cycle before initial use and then cycled each working day to maintain optimal performance.

ALARMS

The Dynamation Combo provides an automatic visual and audible alarm in the presence of dangerous concentrations of combustible or toxic gases and/or an oxygen deficiency. Factory set alarm levels are determined by the model number stamped on the nameplate as follows:

	333	334
Combustible Gases	20% LEL Methane	20% LEL Methane
Toxic Gases	10PPM H_2S	100PPM CO
Oxygen Deficiency	19.5% Volume	19.5% Volume

Other factory set alarms are available on request.

Besides being able to detect the gases at the levels in the chart above, the Combo can be used to protect the worker from dangerous concentrations of other gases that are flammable, such as butane, propane, etc. The Combo 334 will alarm CO on other oxidizable toxic gases (hydrogen sulfide, trichloroethylene etc.) as though they were CO. The Combo 333 toxic sensor is quite specific to hydrogen sulfide; however, it will be affected by nitrous oxide which can be a by product of combustion as in cigarette smoke.

CAUTION: The Dynamation Combo 334 will alarm in potentially lethal exposures of most oxidizable toxic gases but may not alarm at levels low enough to satisfy Federal Safety Regulation if the gas is other than CO.

OPERATION

Turn the Combo on with the OFF/ON switch. The warm-up cycle is automatically activated each time the unit is turned on and is indicated by the green ON light with the RED and ORANGE lights flashing. During warm-up cycle, the alarm horn is deactivated.

The warm-up cycle normally lasts about 5 minutes. When the cycle is complete, the red and orange lights will automatically turn off, while the green light remains on indicating the unit is operational and ready to use.

After warm-up, the unit could be in alarm for the following reasons:

1) Warm-up area gas concentration is above alarm level.
2) Sensors are very contaminated with vapors and particulates, and needs longer warm-up. Turn unit off and then on again, initiating another warm-up. This condition occurs when unit is exposed to heavy vapors or not recently operated.
3) Improper calibration - see Recalibration section.

CALIBRATION OF OXYGEN-DEFICIENCY ALARM

The oxygen-deficiency alarm on the Combo should be calibrated before each use. The calibration control is located on the front panel of the monitor and a screwdriver is provided for easy adjustments.

Wait 5 minutes after warm-up is completed to insure stabilization of the sensors and proceed as follows:

1) With the unit in a known normal oxygen-level environment, push the test switch to the TEST position.
2) If the yellow light comes on and the horn activates, turn the oxygen adjustment pot clockwise until both the yellow light and the horn turns off. If the yellow light and the horn do not activate, proceed with Step 3.
3) While holding the test switch in the TEST position, turn the oxygen control pot counter-clockwise until the yellow light comes on and the alarm sounds.
4) Release the test switch and the alarm should turn off.
5) Activate and release the test switch again to verify the yellow light and audible alarm come on when the switch is activated, and go off when the switch is released.

DANGER: Should you be unable to successfully adjust the oxygen alarm as above, the oxygen cell is at the end of its useful life and must be replaced.

USAGE

The Dynamation Combo is designed for both pre-entry testing of a space and continuous monitoring after entry. A typical test and entry into a confined space should proceed as follows:

1) If the space has a sampling port for pretesting, use the optional Dynamation Aspirator attachment with wand (model #7707-006) for drawing a sample of the atmosphere from the area inside the access opening. This is done to eliminate the risk of igniting combustible gases from static sparking while opening the hatch or manhole cover as well as eliminating the risk of toxic exposure to the workers upon initial opening of the cover. The squeeze bulb should be squeezed 3 times for each foot of hose to make certain that air from the confined space has been successfully drawn to the instrument for testing. If no alarms sound after one minute, the aspirator may be removed from the Combo and the hatch or manhole cover may be opened.

2) Lower the Combo into the manhole or confined space on a rope attached to the swivel connector on the top of the unit. Gases heavier than air are likely to be found low in the workspace while gases lighter than air are likely to be found high so it is important to test the entire workspace (high and low) prior to actual entry of the worker into the confined space.

3) If alarms have not sounded after steps one and two above, safe entry into the space can be made with the detector either on the person or left hanging in the space attached by a rope. Upon entry, further testing throughout the space should be carried out in any parts of the enclosure inaccessable during the pre-entry testing.

4) Keep the detector running while the workers are in the space to automatically warn in case of a gas buildup at any time after entry.

CAUTION: Do not submerge unit in any water or liquid. It may cause permanent damage to the sensors or the electronic package.

DANGER: Do not use the unit after low battery alarm sounds. It can not detect gas without satisfactory battery power. Unit will automatically shut-off about 15 minutes after low battery alarm.

CAUTION: Test at least one minute for an alarm before concluding the air is safe.

DANGER: Do not enter any area if the Combo indicates the presence of gas until the space is safe.

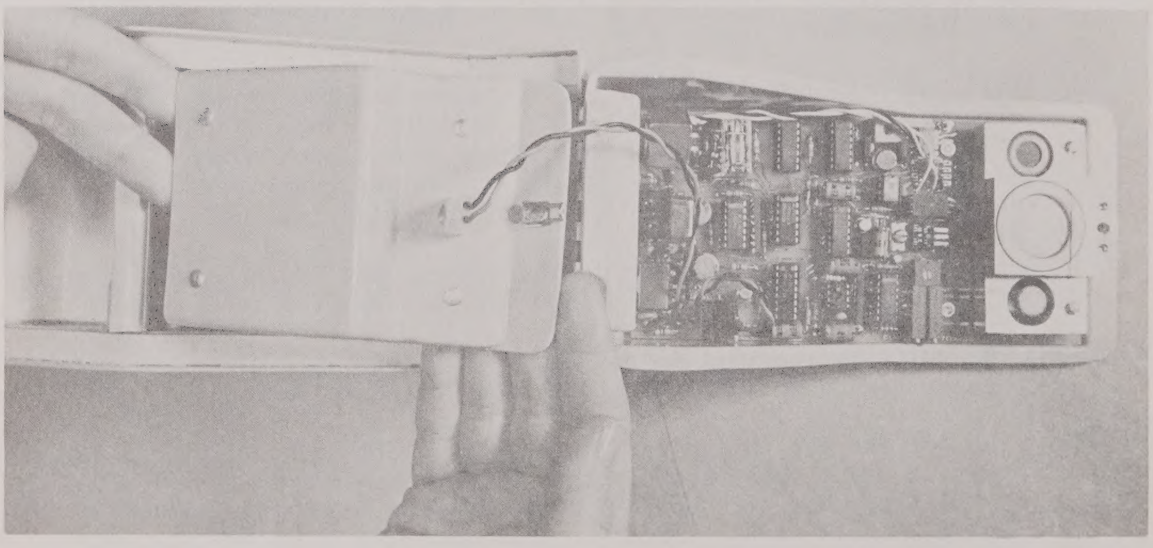
EXCHANGE BATTERY PACKS

To exchange the battery packs:

1) Turn the unit off.
2) Open the instrument case with the allen wrench provided with the monitor.

CAUTION: When the monitor case is open, take care not to damage the teflon membrane on the top of the oxygen cell. Do not touch the top of the cell. Dirt or fingerprints will reduce the amount of oxygen entering the cell and will produce low or erratic outputs. Damage to the cell will void warranty.

3) Slide the battery pack latch back to free the battery pack. Lift out the battery pack.
4) Insert a freshly charged pack by placing the tab on the pack under the retaining lip on the case. Push the pack down over the stud and slide the latch forward to hold the pack.
5) Push the battery lead connector plug into the outlet in the pack until it seats firmly and the locking ears in the plug are fully engaged.
6) Turn unit on. Allow for warm-up cycle.



CALIBRATION

COMBO 334 CALIBRATION

The routine calibration procedure should proceed as follows:

1) Turn on the monitor and allow it to go through the warm-up cycle as described earlier in this manual. Allow an additional 30 minutes to completely stabilize the monitor in order to prevent calibration error.
2) Set the oxygen calibration as described on Page 4 of this manual.
3) Open the monitor using the allen wrench provided.
4) From the calibration kit, select the regulator valve and flow meter that has moisturizing sponge assembly attached. Before placing on the gas cylinder, run clear water through the hose barb to wet the sponges. This is necessary to moisturize the very dry test gas to a humidity level closer to normal air in which the monitor will be used. Shake out any excess water and be sure the valve is closed before proceeding further.
5) Connect end of the plastic tubing to the hose barb on gas valve assembly and attach valve to #7800-003 test gas cylinder. Place calibration cup over the aluminum block containing the three sensors.
6) Turn the gas valve on until the flow meter reads 0.5 cu.ft./hr. flow.
7) Turn both combustible and toxic alarm controls 3-4 turns clockwise. After 1 minute of gas flow, turn toxic alarm control counter-clockwise until its alarm triggers.
8) Turn the gas valve off and replace the toxic test gas cylinder with the combustible gas cylinder #7800-010. Turn the gas valve on until the flow meter reads 0.5 cu.ft./hr. flow.
9) Generally, the oxygen alarm (yellow light and horn) will trigger first. This simply verifies the validity of the oxygen calibration performed in Step 2 above, since the test gas has only 19% oxygen. You may turn the oxygen calibration control clockwise to eliminate the alarm for the remainder of the calibration procedure.
10) After 1 minute of gas flow, turn the combustible alarm control counter-clockwise until its alarm triggers.
11) Turn the gas off and remove the valve assembly from the gas cylinder. Also remove calibration chamber and tubing from the unit.
12) Inspect the Combo's case for cracks, dirty filter, etc. before returning it to use.
13) Set the oxygen calibration as described on Page 4 of this manual.
14) Close the monitor and secure the cover using the allen wrench provided.

CAUTION: Should the Combo fail any of the calibration tests, consult the test voltage and troublshooting section of the manual or have the unit inspected by a qualified technician before using the detector to protect human life.

COMBO 333 CALIBRATION

Read carefully the permeation kit directions on its operation before proceeding with following Combo 333 calibration instructions.

1) Turn on the monitor and allow it to go through the warm-up cycle as described earlier in this manual. Allow an additional thirty minutes to completely stabilize the monitor in order to prevent calibration error.

2) Open the monitor using the allen wrench provided.

3) From the calibration kit, select the regulator valve and flow meter that has moisturizing sponge assembly attached. Before placing on gas cylinder, run clean water through the hose barb to wet the sponges. This is necessary to moisturize the very dry test gas to a humidity level closer to normal air in which the monitor will be used. Shake out excess water and be sure the valve is closed before proceeding further.

4) Connect end of the plastic tubing to the hose barb on gas valve assembly and attach valve to #7801-010 test gas cylinder.

5) Turn gas valve on until flow rate is the amount calculated in permeation kit directions. After flowing gas through system for 1-2 minutes, place calibration cup over aluminum block that contains the three sensors.

6) Turn both combustible and toxic alarm controls fully clockwise. After (2) minutes of gas flow, turn combustible alarm control counter-clockwise until it's alarm triggers and then turn toxic control until it alarms.

7) Turn the gas off and remove the valve assembly from the gas cylinder. Also remove calibration chamber and tubing from unit.

8) Inspect the Combo's case for cracks, dirty filter, etc. before returning it to use.

9) Set the oxygen calibration as described on page 4 of this manual.

10) Close the monitor and secure the cover using the allen wrench provided.

CAUTION: Should the Combo fail any of the calibration tests, consult the trouble shooting section of this manual or have the unit inspected by a qualified technician before using the detector to protect human life.

TESTING COMBO 333 FOR HYDROGEN SULFIDE RESPONSE

The following test is for checking the hydrogen sulfide sensor's response to gas and calibrating the methane alarm point. To calibrate the hydrogen sulfide alarm point, hydrogen sulfide gas is required as used in the calibration procedure previously described. The reason for a test procedure (instead of calibration) is the cost and inconvience of calibrating with hydrogen sulfide gas although Dynamation's Dynacal Permeation System is relatively inexpensive and easy to use in comparison with other units.

1) Turn on the monitor and allow it to go through the warm-up cycle as described earlier in this manual. Allow an additional thirty minutes to completely stabilize the monitor to prevent calibration error.

2) Open the monitor using the allen wrench provided.

3) From calibration kit, select the regulator valve and flow meter that has moisturizing sponge assembly attached. Before placing on gas cylinder, run clean water through the hose barb to wet the sponges. This is necessary to moisturize the very dry test gas to a humidity level closer to normal air in which the monitor will be used. Shake out any excess water and be sure the valve is closed before proceeding further.

4) Connect end of the plastic tubing to the hose barb on gas valve assembly and attach valve to #7800-010 test gas cylinder.

5) DO NOT MOVE TOXIC ALARM CONTROL.

6) Turn combustible alarm control fully clockwise. After one minute turn combustible alarm control counter-clockwise until its alarm triggers.

7) Disconnect gas cylinder #7800-010 and connect H_2S simulation gas cylinder #7800-007 to the valve.

8) DO NOT MOVE TOXIC ALARM CONTROL. If the unit alarms Hydrogen Sulfide within one minute, sensor is responding to gas and alarm circuit is operational.

CAUTION: It does not mean it will alarm at a known concentration of Hydrogen Sulfide.

SENSOR REPLACEMENT

Sensor replacement requires only a few minutes by using the following proceedure.

1) Referring to the sketch, remove the two screws that attach metal block to circuit board.

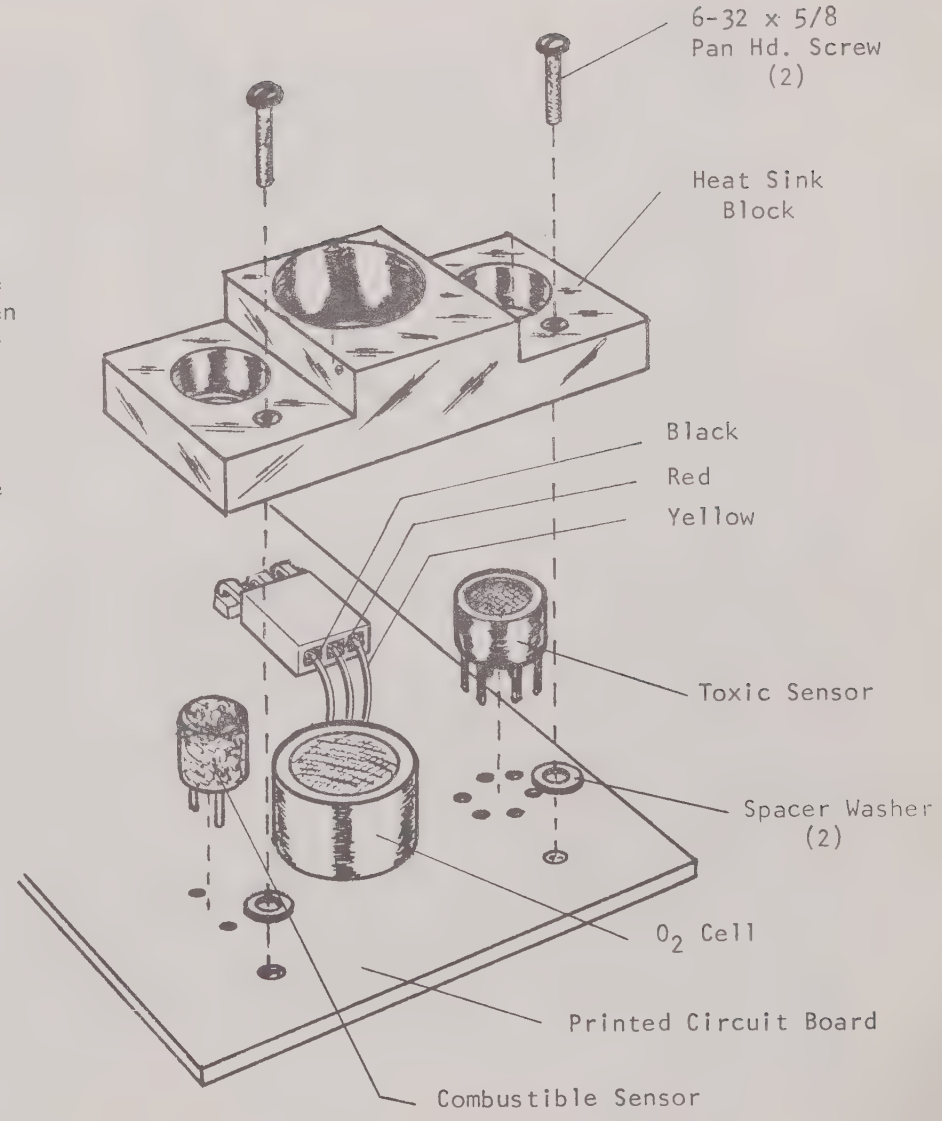
2) After removing metal block, unplug combustible and/or toxic sensor from circuit board. Oxygen cell unplugs at electrical circuit board connector. Note wire colors and their initials are marked on circuit board.

3) Plug in combustible and/or toxic sensors into circuit board. Polarity or direction of these sensors is not important.

4) Plug in oxygen cell electrical connector to circuit board connector. Be sure that the colored wires are in the same position as marked on circuit board.

5) Replace metal sensor block and fasten to this board with screws. Be sure that oxygen cell wires are in position not to be injured when case is closed.

6) Recalibrate unit after sensor replacement as described in calibration section.



BATTERY CARE

The Dynamation Combo is powered by a custom designed removable battery pack consisting of 6 heavy duty nickel-cadmium rechargeable batteries. You should be able to cycle your battery from 300 to 500 times over a period of 1-3 years before battery failure.

Before initial usage, charge your Combo for 14-16 hours and discharge until the low battery alarm sounds. Repeat this charge-discharge cycle 2-3 times. After this initial break-in the Combo should be left on charge at all times when not in use. This charging should be conducted in an area where the temperature will remain about 70°F. The cells are designed to be full charged at a standard rate of 14-16 hours but can and should be left on charge continuously if the room temperature is not significantly different from 70°F.

NOTE: Any time your Combo has been stored for a long period of time off the charger repeat the break-in procedure before resuming continuous charging.

You can help maximize your battery life by following a few guidelines:

1) Allow a battery which has been outside in the cold to warm to room temperature before charging.

2) Never use a charger which is designed for some other battery system.

3) Charge only for the minimum recommended time period (14-16 hours) the first few cycles the Combo is put into service.

4) Leave the Combo on charge at all times when not in service after the initial break-in.

WARRANTY

DYNAMATION, INC. warrants each new electrical product manufactured by it to be free from defective material and workmanship and that all such product is warranted as to its merchantability and fitness for the purpose intended, for a period of one (1) year from the date of sale to the original purchaser, and agrees to remedy any such defect or to furnish a new part (at the Company's option) in exchange for any part of any product of its manufacture which under normal use and service disclosed such defect; provided, the product is delivered by the purchaser to DYNAMATION'S factory, in tact, for our examination, with all transportation prepaid to our factory, provided that such examination discloses, in our judgement, that it is defective.

This warranty does not extend to any products which have been subjected to misue, neglect, accident, unauthorized modifications or to use in violation of instructions furnished by us, nor does it extend to products which have been repaired or altered outside of our factory. THIS WARRANTY IS IN LIEU OF ALL WARRANTIES EXPRESS OR IMPLIED AND NO REPRESENTATIVE OR PERSON IS AUTHORIZED TO ASSUME FOR US ANY OTHER LIABILITY IN CONNECTION WITH THE SALE OF OUR PRODUCTS. ALL IMPLIED WARRANTIES ARE LIMITED TO THE DURATION OF THIS WRITTEN WARRANTY. IN NO EVENT IS DYNAMATION, INC., LIABLE FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING FROM ANY BREACH OF WARRANTY OF PRODUCT.

REPLACEMENT PARTS AND ACCESSORIES

REPLACEMENT PARTS

5701-008 Oxygen Cell

5502-002 Combustible Sensor

5501-007 H_2S Sensor (333)

5501-001 Toxic Sensor (334)

4001-001 110vAC Charger

7707-003 Calibration Connector

ACCESSORIES

7707-011 Calibration Kit for 334

7707-012 Calibration Kit for 333

7707-013 Alarm Test Kit for 333

7707-006 Aspirator Attachment w/ manhole wand

4001-003 12vDC Charger

4002-001 Spare Battery Pack w/ pigtail

2601-011 Porous Plastic Screens (pkg. of 10)

TEST GAS

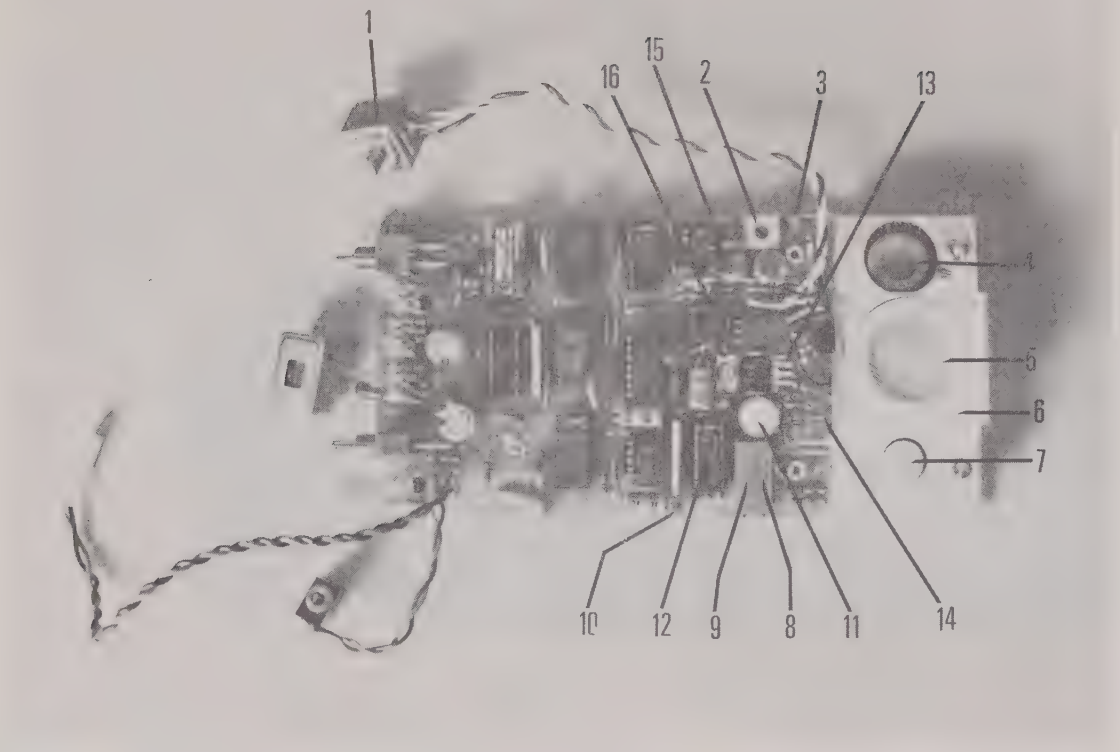
7801-010 Test Gas - 20% LEL Methane, 19% Oxygen (0.75 cubic ft.)
(Replacement for 7707-012 Cal Kit for 333)

7800-012 Test Gas - H_2S Permeation Device
(Replacement for 7707-012 Cal Kit for 333)

7800-010 Test Gas - 20% LEL Methane, 19% Oxygen (0.6 cubic ft.)
(Replacement for 7707-013 Alarm Test Kit for 333 & 7707-011 for 334)

7800-003 Test Gas - 100 PPM Carbon Monoxide
(Replacement for 7707-011 Cal Kit for 334)

INTERNAL IDENTIFICATION



1. O_2 Calibration Adjustment (outside)
*2. Primary Voltage Adjustment
3. Test Point - GROUND
4. Toxic Sensor
5. Oxygen Sensor
6. Heat Sink Block
7. Combustible Sensor
8. Toxic Calibrate Adjustment
9. Combustible Calibrate Adjustment
10. Test Point - COMBUSTIBLE Adjustment
*11. Heater Balance Adjustment
12. Test Point - TOXIC Adjustment
13. Test Point - PRIMARY HEATER VOLTAGE
14A. Test Point - TOXIC HEATER
14B. From T.P. 14 to T.P. 13 - COMBUSTIBLE HEATER VOLTAGE
15. Battery Voltage (circuit foil)
16. Test Point - O_2 CELL OUTPUT

*NOTE: Do not adjust heater controls (2 & 11) unless changing sensors.

TEST VOLTAGES AND TROUBLESHOOTING

All test points are measured from GROUND (T.P. 3), except the COMBUSTIBLE HEATER VOLTAGE (T.P. 14B).

TEST POINT	DESCRIPTION	CONDITION	VOLTAGE RANGE
3	Ground	---	---
10	Combustible Calibration Adjustment	Clean Air	approx. 3.5 to 4.0vDC
		20% LEL Methane	2.0 to 2.5vDC
12	Toxic Calibration Adjustment	Clean Air - 333	approx. 0 VDC
		Clean Air - 334	approx. 5.5vDC
		10 PPM H_2S - 333	2.0 to 2.5vDC
		100 PPM CO - 334	2.0 to 2.5vDC
*13	Primary Heater Voltage	Clean Air H_2S 333-4.05	5.8 ± .08vDC
*14A	Toxic Heater Voltage	Clean Air - 333 <-->	2.5 ± .03vDC
		Clean Air - 334	4.25 ± .05vDC
*14B	Combustible Heater Voltage (ground lead to T.P. 14B) (positive lead to T.P. 13)	Clean Air	1.55 ± .03vDC
15	Battery Voltage (circuit foil)	Full Charge	7.8 to 8.2vDC
		Operational	6.8 to 8.2vDC
16	O_2 Circuit Output Test Point	Calibrated	approx. .40vDC
		Alarm Full ON (CCW)	.02vDC
		Alarm Full OFF (CW)	.45 to approx. 1.4vDC

*NOTE: Do not adjust heater controls (2 & 11) without reading paragraphs on heater voltage adjustments. Should only need readjustment if sensors have been changed.

HEATER VOLTAGE ADJUSTMENT - Read Instructions First!

1. With instrument off and combustible sensor not plugged in, set heater balance adjustment fully clockwise (lowest setting for combustible heater). Turn instrument on.
2. Set primary heater voltage (use PRIMARY HEATER VOLTAGE ADJUSTMENT, #13) to: a) 5.8vDC for 334, or b) 4.05vDC for 333.
3. Install combustible sensor.
4. Set combustible heater voltage (T.P. 14B) to 1.55vDC ± .03vDC using HEATER BALANCE ADJUSTMENT, #11.
5. Toxic heater voltage (T.P. 14A) should now be at 2.50 ± .03vDC for 333, or 4.25 ± .05vDC for 334.
6. If necessary, make MINOR adjustment until voltages are correct. Monitor T.P. 14B closely to prevent sensor burn-out. The combustible heater will burn out if the combustible heater voltage rises above 1.80vDC.

Combo Series

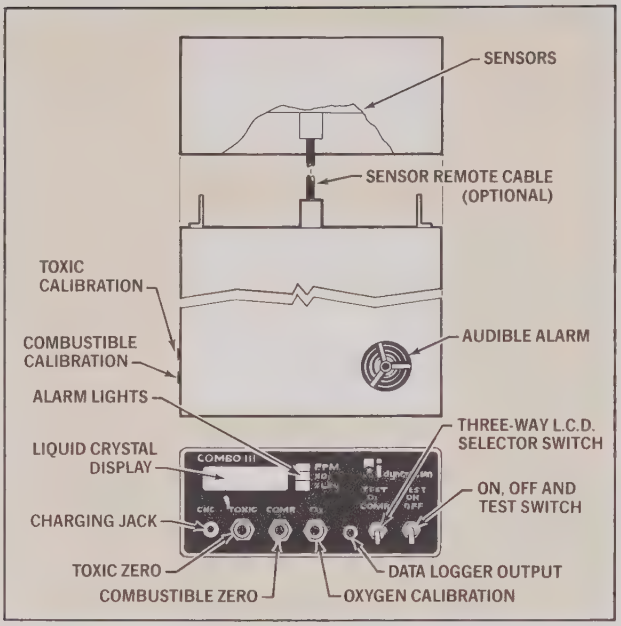
Combination Gas Detection Instrument No. 314 for Oxygen, Combustible and Carbon Monoxide Gas

Combo III C Gas Detection Instrument

Accurately Measures and Warns of the Presence of Dangerous Gases

The Combo III C monitors the atmosphere for the presence of three types of hazardous conditions; Combustible gases, Carbon Monoxide gas and Oxygen Deficiency. Simply turn on an On-Off switch and the instrument is operational in 30 seconds. The unit continuously monitors for all three conditions simultaneously and will give an audible and visual alarm when gas conditions exceed the preset alarm values. The level of the gas is shown on a Liquid Crystal Display readout. (L.C.D.) Three individual alarm lights pinpoint the condition when the audible alarm is heard and the L.C.D. automatically displays the measurement of the hazardous condition. When the unit is not in alarm, a three way selector switch will place the L.C.D. display in either combustible, toxic or oxygen readout for taking measurements. The appropriate alarm light will indicate the gas being measured.

Designed to be used during confined space entry and as an all purpose gas detector, the portable Combo III C is powered by a rechargeable cell that gives up to 10 hours of continuous operation before recharging is required. An additional feature is a low battery alarm that automatically sounds a steady alarm tone for 15 minutes and then turns the unit off to protect the battery from damage. Lightweight portability, infrequent calibration requirements and simple operation make the Combo III C outstanding in the field of portable instruments.



Latest Sensor Technology

The Combo III C utilizes the highest quality sensors. The Combustible gases are detected by a matched pair of Platinum Wire Beaded sensors that have proven performance in the mining industry for many years. The Carbon Monoxide and Oxygen sensors are the latest design in chemical cells, giving long life, excellent repeatability and fast warm up.

Features

- **Continuously Measures and Alarms for Combustible, Carbon Monoxide Gas and Oxygen Deficiency**
- **Sounds Pulsating Alarm when Air is Unsafe**
- **Liquid Crystal Display Automatically Switches to Gas that is in Alarm**
- **Simple Operation**
- **10 Hour Continuous Operation before Recharging**
- **Operational in 30 Seconds After Turn On**
- **Low Battery Alarm and Electronic Circuit Shut-off**
- **Built in Remote Sensor Capability**
  Includes Battery Charger and Leather Case
- **Data Logger Output Standard**

Accessories

Calibration Kit includes gas valve, calibration connector and flow meter, No. 7800-010 Methane gas cylinder, No. 7800-004 Carbon Monoxide gas cylinder, screw driver and carrying case.

Stock No. 7710-001

Aspirator Attachment with Manhole Wand	Stock No. 7710-003
Interference Filters (Package of 10)	Stock No. 7710-004
Battery Charger, 12 v DC	Stock No. 8000-067
Remote Sensor Cable, 20 ft.	Stock No. 7710-005

Specifications

	Combustible	Carbon Monoxide	Oxygen
Linear Range	0-100% LEL	0-100 ppm	0-100% V
Preset Alarms	20% LEL	50 ppm	19.5% V
Sensor Type	Plat. Hot Wire	Chemical Cell	Chemical Cell
Response	90% in 5 seconds	90% in 30 sec.	90% in 30 sec.
Alarm Horn	Pulsating	Pulsating	Pulsating
Alarm Lights	Flashing Red	Flashing Yellow	Flashing Green
Accuracy	±3% LEL	±3 ppm	±1% V
Warm Up	less than 3 sec.	less than 10 sec.	less than 10 sec.
Temperature Range (Short Time Exp.)	0°-120°F -20°-130°F	32°-100°F 0°-120°F	32°-100°F 0°-120°F
Expected Life	2 years	1-2 years	1-1½ years
Sensor Life Warranty	1 year	6 months	1 year
Detectable Level	1% LEL	1 ppm	.5% V
Humidity	0-99% RH	Int. 0-99% RH Cont. 35-90% RH	0-99% RH

DISTRIBUTED BY

dynamation, inc.
3784 plaza drive
ann arbor, michigan 48104
(313) 769-0573

©Dynamation, Inc. 1982 Printed in U.S.A.

Bulletin Number 8210-314-A

INSTRUCTION MANUAL

COMBO III

The COMBO III measures the level of combustible, toxic and oxygen on its digital display and alarms when the concentration exceeds its preset threshold limits. Your COMBO III operated as described herein should give years of trouble free operation.

NOTE: ALL GAS DETECTION SENSORS HAVE A FINITE LIFE EXPECTANCY. ALWAYS CHECK YOUR INSTRUMENT FOR PROPER OPERATION BEFORE USING.

MODEL COMBO III - STOCK NO. 313

Meter	Calibration	Standard Factory Alarm Levels	Sensor Life Expectancy
H_2S	0-100PPM	10PPM	1 to 1 1/2 yrs.
O_2	0-100% Vol.	19.5% Vol.	1 to 1 1/2 yrs.
CH_4	0-100% LEL	20% LEL	2 to 3 yrs.

MODEL COMBO III - STOCK NO. 314

Meter	Calibration	Standard Factory Alarm Levels	Sensor Life Expectancy
CO	0-500PPM	50PPM	1 to 1 1/2 yrs.
O_2	0-100% Vol.	19.5% Vol.	1 to 1 1/2 yrs.
CH_4	0-100% LEL	20% LEL	2 to 3 yrs.

DESCRIPTION

General

The COMBO III utilizes hot wire and chemical cell sensors, modern integrated circuits, LCD display, LED alarm lights, rechargeable lead acid battery and is packaged in rugged aluminum enclosures with a leather case added for protection and appearance.

Configuration

The COMBO III is housed in two metal enclosures attached by a mil spec electrical connector. The sensors are self contained in one enclosure which may be removed from the readout enclosure by two thumb screws. This design permits optional remote probe operation by placing a cable between the display module and sensor modules. The leather case provides "D" rings for attaching a shoulder strap and a belt loop by snapping the cover flap to the back of the instrument.

A charger specially designed for recharging this lead acid battery is in a molded plastic housing with part #8000-037 stamped on it. Only this charger should be used with the COMBO III. The charger provides a regulated charge to the battery pack and may be continuously plugged into the unit.

Switches

Two three way switches operate the COMBO III. The OFF/ON/TEST switch applies full power to the circuits in the ON position and tests the alarm horn while in the momentary TEST position. It is called the ON switch. The other three position switch selects COMBUSTIBLE, TOXIC or OXYGEN display on the LCD readout. It is called the READOUT switch. This switch position is indicated by markings above the switch and also by the LED ALARM/POSITION LITE that is illuminated.

An auto display feature automatically overrides the "READOUT" selector switch when one alarm condition exists. For example - if the selector switch was in the OXYGEN position displaying OXYGEN on the meter and a COMBUSTIBLE gas condition exceeds its alarm point, the unit would automatically switch and display COMBUSTIBLE concentration on the LCD meter. If more than one gas is in alarm the mechanical "READOUT" switch is used to display the gases on the meter while the flashing alarm LED's indicate which gases.

Controls

External Adjustable

There are three front cover and two side panel controls on the display module. The front cover controls are the OXYGEN CALIBRATION, TOXIC and COMBUSTIBLE ZEROS. These three controls can be adjusted with the instrument in standard air. Usually the COMBUSTIBLE is set to zero, TOXIC set to or near zero and OXYGEN to 29.9% in standard air. The two side controls are for COMBUSTIBLE and TOXIC calibration and should only be set with a known concentration of gas applied to the sensors such as test gas.

Internal Adjustable

Three alarm set point controls are located inside the display enclosure as shown in figure 2. Do not adjust the reference voltage control, also shown next to the alarm controls.

Readout

The unit utilizes a liquid crystal display with continuous back lighting illumination.

Indicators

Three square LED's indicate the position of the "READOUT" selector switch and the gas that is being shown on the LCD display. In the non alarm condition the LED shows a steady (non-flashing) light for the gas being displayed.

LED Color	Gas Type	Meter Concentration
Yellow	Toxic	PPM (Parts per million)
Green	Oxygen	% V (Volume)
Red	Combustible	% LEL (Lower explosive level)

Alarms

The COMBO III provides an audible and visual display of a gas alarm. A pulsating SONALERT horn indicates a gas condition and the flashing LED shows the type of gas or gases in alarm. A steady horn indicates a low battery alarm. After 15 minutes in low battery condition the unit will electronically shut itself off if the switch is not turned off first. This saves the battery from a complete discharge.

OPERATION

1. Turn COMBO III on with OFF/ON/TEST switch.
2. Place unit in TEST position where a reading of about 90 should appear on meter with red LED illuminated. The alarm horn should be emitting a pulsating sound while the switch is in its momentary TEST position.

3. If a steady tone is observed after turning the unit on, it is in low battery alarm and requires recharging. If the unit doesn't turn on it may have so low a battery that the circuits won't operate because of the auto cutoff feature and it requires recharging. Turn the ON switch off while recharging.

4. After the unit has been on for a couple of minutes, set COMBUSTIBLE to read zero, TOXIC to read 0 - 3 PPM* and OXYGEN to read 20.9% on the meter in standard air by moving the "READOUT" selector switch to each position and adjusting their respective front panel controls.

   *For COMBO III CO standard air contains 0 to 3 PPM CO. For H_2S it may be set to read 0 PPM.

5. The COMBO III is ready for measuring and monitoring the gases for which it has been calibrated.

6. Place unit on charger after usage. Charge unit with only battery charger that is supplied with unit. COMBO III requires 2 hours of charge for each hour of operation. A full charge should give over 11 hours of operation.

OPERATION GAS CHECKS

Learn where the sensors are located in the sensor housing so that these tests may be applied directly to the sensor of interest - see figure #3.

A. Oxygen - Exhale lung air slowly and continuously over the oxygen sensor. The oxygen level on the meter will decrease by 3 to 7% volume and oxygen alarm will flash and sound.

B. Combustible - Using a butane lighter, exhaust butane over the active methane sensor. Note that there are two combustible sensors - an active and reference. Placing gas only on the reference will give a negative meter reading. It takes a little experimenting to detect the butane on the active sensor since it is a small area under the sintered metal screen.

C. Carbon monoxide - Inhaled cigarette smoke can be exhaled over the CO sensor and the meter may climb to 50 PPM. Do not place smoke from the lit end of a cigarette under the sensor as it contains contaminates that will injure the sensor in repeated tests.

D. Hydrogen sulfide - No test that is easy to perform.

NOTE: We strongly urge that Dynamation's * calibration kit be used for testing in lieu of the above tests for combustible and toxic. As a test, it only requires a few minutes to check all three gases with known concentrations.

* Calibration Kit: #7710-001 for CO
#7710-002 for H_2S

CALIBRATION

The combustible and toxic calibrations have consistently required minimum recalibration over long periods of time. These sensors are designed for minimal drift with temperature and humidity compensation, etc. However, they do have a life cycle and must be checked for operating performance and accuracy periodically.

The following provides a procedure for calibrating the COMBO III instrument. It is highly recommended that Dynamation's test kits* be utilized as they contain all the proper equipment.

1. Turn unit ON and let all sensors and circuits stabilize for 10 minutes.
2. Place a calibration cup or bag over the entire sintered metal sensing area. Be sure there is a good seal between the calibration device and the sensing area.
3. Flow test gas at about 1 cu. ft. per hour on the sensing area. It is recommended that 50% LEL be used for combustible, 200 PPM CO and 19% volume oxygen. While the alarm points may be different than the test gas concentrations, using gas in the middle of sensors' linear range (except for oxygen) will give better meter scaling. It is desired to keep the oxygen level higher when oxygen is in a mixed test gas with methane since the methane sensors won't operate properly in low oxygen levels.
4. Prior to using concentrations of test gas, be sure the combustible and toxic readings are zero and the oxygen is at 20.9% volume. If clean air is not available to set the toxic at zero, impurity free air #7800-006 may be used.
5. With the test gas applied, wait for the meter reading to stabilize and then turn the calibration control to the value of the test gas. The control marked "C" is for combustible and "T" for the toxic gas. Move the "READOUT" selector switch to the gas that is being calibrated. If one gas is in alarm the unit automatically switches to it. If this is not the gas of interest, change the zero or calibration (oxygen) of the alarming gas to turn off its alarm. Then the value of the gas of interest can now be selected on the meter. If more than one gas is in alarm, the "READOUT" selector can be used to manually select the gas to be monitored on the meter.
6. After combustible and toxic calibration, check that the meter returns to zero on these gases and 20.9% on oxygen.

* COMBO III Stock No. 314 utilizes Test Kit #7710-001

COMBO III Stock No. 313 utilizes Test Kit #7710-002 and #7710-007. See accessory section.

ALARM ADJUSTMENTS

Alarm controls for combustible, toxic and oxygen are placed inside the display enclosure to protect from accidental tampering and because of the infrequent needed use. They are factory set at 20% LEL methane, 19.5% V. oxygen and either 50 PPM CO or 10 PPM H_2S depending on the Combo model

To change alarm points refer to figure 2 for location of alarm adjustments on the printed circuit board.

1. Remove instrument's cover by unscrewing top row of fasteners on side of instrument (not on sensor module).
2. With "READOUT" switch, display gas that alarm point is to be changed.
3. Turn the zero controls on front panel (calibration control for oxygen) to read desired alarm level.
4. Turn appropriate alarm control until the alarm just triggers.
5. Check alarm point setting accuracy by turning zero control (or calibration control if oxygen) until alarm turns off and then turning until alarm triggers.
6. Replace cover and reset zero or calibration to proper levels.

USAGE INFORMATION

Battery Charging

It is recommended that the Combo be plugged into it's charger when not in use. A very small current is being used with the unit off to keep the toxic sensor ready for operation. Keeping the unit on charge will always give the full eleven hours of use before recharging.

Temperature

All sensors have temperature compensation devices. Major deviations from standard temperatures of 32° F (0° C) to 104° F (40° C) will affect readings. Where temperature excursions are significant, it is important to either:

1) Take readings quickly or
2) Wait for read-out to stabilize before recording

By taking the toxic and oxygen readings within a few moments after exposing the unit to a different temperature, the cell will not have a chance to change temperature and thus give accurate reading. During a rapid temperature change, the compensation circuits and cells outputs may not match until cell temperature stabilizes.

Severe temperature extremes should be avoided in use and in storage. The oxygen sensor will be damaged if cell temperature exceeds 104° F (40° C) or falls below 32° F (0° C). For short periods the cell may be exposed to 0° F and higher than 120° F as long as the cell temperature itself does not exceed the 32° to 104° F range.

Humidity

Humidity range of 0 - 90% RH is acceptable as long as operation in less than 35% RH or greater than 90% RH is not continuous. The unit shouldn't be operated in 100% RH areas where condensation forms on the sensors.

Sensor Poisoning

Certain gases and substances can temporarily impair or completely poison the combustible sensors. Refer to poison and inhibitor section in general information combustible sensor section.

OPTIONAL REMOTE PROBE OPERATION

To operate with the sensor housing (remote probe) detached, remote sensor cable #7710-005 is required with a length of 20 ft. Longer lengths can be supplied - please contact factory or your distributor if needed.

Remove the remote probe from the display unit by unscrewing the two thumb screws on sintered metal sensor housing. Be sure that these screws are turning free before pulling the housing apart. A slight amount of pull is required as a multipin connector is being separated.

Place the remote cable connectors into the respective connectors on the display module and remote probe. Be sure that the connectors screws are tight so that the probe will remain connected.

To place the probe back on the display module reverse the probe procedure being careful to match top and bottom of pin connector. The remote probe will not commence connecting until the screws begin to engage. Turn one screw, then the other for best results.

Using the remote probe is similar to operating with sensor housing attached. Be sure to place probe to bottom of a confined space but do not immerse in any liquid. Wait a few seconds for reaction and reading to occur to be sure area is safe.

If longer than 50 ft. of remote cable is used, combustible calibration should be checked the first time cable is installed to notice any difference between remote and non-remote calibration.

GENERAL INFORMATION - COMBUSTIBLE

Bases of Operation

Two catalytic gas detectors are supplied as a matched pair, one of which is an active catalytic detector and the other a non-active compensating element. Each detector consists of a coil of very fine platinum wire embedded in a bead of alumina to which, in the case of the detecting element, a catalytic mixture is applied. In the case of the compensating element, the bead is treated so that catalytic oxidation of gas does not occur.

The two elements are connected in a Wheatstone bridge circuit. Its output is electronically processed to give a digital display on the meter. The bridge circuit is utilized to compensate for temperature, humidity and any sensor deterioration over time. The bridge output is sufficient to allow for recalibration over many thousands of hours of use.

The output from the modified bridge is substantially linear up to 100% LEL of methane and will continue to increase up to 200% LEL of the gas. After 200% LEL the reading will decrease because of the lack of oxygen for the catalytic oxidation process to take place. The LCD reading will not decrease below 100% LEL until the concentration of methane in air is above 600% LEL.

When the methane concentration is 200% LEL there is 2.1% volume less oxygen in the air. The Combo's oxygen meter will read 18.8 and be in alarm. Therefore, the instrument is fail safe in that when it is not properly reading methane, it will be in oxygen alarm.

Response Time

The time for the detectors to respond to the presence of methane in air is very short, typically two seconds to register 25% LEL in a 50% LEL concentration. Response time will also depend upon the amount of diffusion and filtering used.

High Gas Concentration

Tests have shown that for periods up to about 2 minutes, 10 second bursts of 8%, 10% and 80% methane in air have had no adverse effect. Prolonged exposure can result in zero drift which may be reversible by operation for a short period in air or low methane concentration (20% LEL). Exposure to 40% concentration for longer periods will begin to destroy the detector surface altering the zero reading and reducing sensitivity.

POISONS AND INHIBITORS

Volatile substances which may temporarily impair the sensor are called inhibitors. These are usually substances containing halogens and the detectors may recover after a short period of operation in clean air.

Whenever the substance produces a permanent effect on the catalyst with a catastrophic reduction in sensitivity, the detector is said to be poisoned. Examples are: silicone oils and greases, lead gasoline additives and phosphate esters. Activated carbon filters can be supplied to provide protection from poisoning in the majority of cases.

If problems arise from silicones, etc., consult the factory as special sensors are available for these applications.

RESPONSES TO DIFFERENT GASES

An attractive feature of these detectors is the almost universal response to % LEL of hydrocarbon. Table 1 below lists theoretical factor by which a unit calibrated to methane would respond to other gases using the following formula.

Reading on methane calibrated meter =

(concentration of other gas) (K)

Example:

Butane K = .585
For 50% LEL concentration

Reading on methane calibrated instrument =

(50) (.585) = 29% LEL

Therefore: 50% LEL of butane will read
29% LEL on methane calibrated instrument

TABLE 1

Gas	K	Gas	K
Acetaldehyde	.601	Carbon Disulphide	.177
Acetic Acid	.543	Carbon Monoxide	.754
Acetic Anhydride	.460	Carbon Oxysulphide	.934
Acetone	.516	Cyanogen	.892
Acetylene	.568	Cyclohexane	.411
Alkyl Alcohol	.510	Cyclopropane	.622
Ammonia	1.265	n-Decane	.328
n-Amyl Alcohol	.327	Diethylamine	.487
Aniline	.394	Dimethylamine	.578
Benzene	.407	2,3-Dimethylpentane	.398
Biphenyl	.250	2,2-Dimethylpropane	.397
1,3-Butadiene	.558	Dimethylsulphide	.434
n-Butane	.585	1,4-Dioxane	.446
iso-Butane	.516	Ethane	.677
Butene-1	.454	Ethyl Acetate	.512
cis-Butene-2	.484	Ethyl Alcohol	.728
trans-Butene-2	.506	Ethylamine	.526
n-Butyl Alcohol	.343	Ethyl Benzene	.356
iso-Butyl Alcohol	.529	Ethylcyclopentane	.396
tert-Butyl Alcohol	.742	Ethylene	.706
n-Butyl Benzene	.314	Ethyleneoxide	.517
iso-Butyl Benzene	.320	Diethyl Ether	.462
n-Butyric Acid	.380	Ethyl Formate	.442
Ethylmercaptan	.561	Nitromethane	.579
n-Heptane	.386	n-Nonane	.314
n-Hexane	.368	n-Octane	.374
Hydrazine	.450	n-Pentane	.458
Hydrogencyanide	.477	iso-Pentane	.463
Hydrogen	.766	Propane	.552
Hydrogen Sulphide	.407	n-Propyl Alcohol	.470
Methane	1.00	n-Propylamine	.483
Methyl Acetate	.496	Propylene	.515
Methyl Alcohol	.859	Propyleneoxide	.475
Methylamine	.772	iso-Propylether	.436
Methylcyclohexane	.441	Propyne	.415
Dimethyl Ether	.625	Toluene	.404
Methylethylether	.440	Triethylamine	.398
Methylethylketone	.412	Trimethylamine	.485
Methyl Formate	.670	Vinylethylether	.419
Methylmercaptan	.606	o-Xylene	.358
Methylpropionate	.511	m-Xylene	.391
Methyl n-propylketone	.405	p-Xylene	.391
Naphthalene	.340		

Since these K factors are theoretical, they will only give a guide to the response expected in other gases. For exact conversion factors the instrument should be calibrated using the relevant gases.

GENERAL INFORMATION - OXYGEN

The oxygen cell used in the COMBO is a disposable electrochemical cell; basically it may be thought of as a battery whose current output depends on the concentration of oxygen reaching one electrode. The oxygen reaches the electrode by diffusion through a thin Teflon membrane covering the top of the cell. The Teflon membrane must be kept free of contamination and undamaged for proper operation of the cell. The basic cell reactions are:

Cathode: $4e^- + 2H_2O + O_2$ ---- $4OH^-$

Anode: $2\ OH^- + Pb$ ---- $PbO + H_2O + 2e^-$

The electron (e^-) flow through the external circuit produces the output current proportional to oxygen concentration. A drop in current produced by oxygen deficiency is detected by the circuitry which is displayed on the meter. When the level drops below 19.5% the alarm horn and light is activated. Since standard air contains a constant 20.9% oxygen, it can be used for setting the meter to read 20.9% in standard air.

The cell output current is sensitive to temperature changes. A thermistor is placed inside the cell to compensate for temperature changes. Thermal changes may temporarily show an inbalance between thermistor and oxygen cell, which will be noted on the meter. However, these changes are slow enough to permit correct reading in widely varying temperatures if the readings are taken within a few minutes.

Normal operating temperature range of the oxygen cell is 29° F to 125° F. The COMBO may be used at much lower temperatures provided that the exposures of the oxygen cell to low temperatures is limited in time, so that the cell does not reach a final temperature below 29°F.

The nominal lifetime of the oxygen cell is 18 months in air. Since the cell reactions continue whether the instrument is turned on or not, cell lifetime starts when the cell is exposed to air and ends when the material (Pb) is used up. Replacement cells are sealed in nitrogen gas-tight bags and have a shelf life of a year. Cell output normally is quite steady with time until the end of life; when frequent large adjustments of the O_2 calibration control must be made, the cell should be replaced.

GENERAL INFORMATION - TOXIC GAS

The toxic sensors are of the electrochemical type design to be maintenance free and stable over long periods of time.

The sensors use a special diffusion barrier technology which results in a low temperature coefficient, a direct response to gas concentration while relatively unaffected by pressure.

Carbon monoxide diffusing to the sensing electrode: (anode) reacts according to the equation.

$$\text{Anode:} \quad 2\ CO + 2\ H_2O + 4e^- \longrightarrow 2\ CO_2 + 4H^+$$

At the counter electrode (cathode) the reaction is:

$$\text{Cathode:} \quad O_2 + 4H^+ \longrightarrow 2H_2O + 4e^-$$

The oxygen required to support this reaction is supplied from ambient air.

Response time of sensor to 90% of it's value is 20 - 30 seconds. It's nominal sensitivity to carbon monoxide is 0.1 PPM. The sensor has no orientation sensitivity and is linear throughout stated range.

Its operating temperature range as discussed earlier is 0-40° C with best storage temperature range of 0 - 25° C. In normal operating temperature, the sensor is expected to last 1-2 years and guaranteed for 6 months.

The sensors contain a small volume of strong sulfuric acid. In the unlikely event of a leak the contaminated parts should be rapidly and throughly rinsed in water.

MAINTENANCE

Sensor replacement may be accomplished by the following procedure:

1. Remove remote probe module from the display module.
2. Remove top of remote module with top four (4) side screws.
3. Remove four (4) screws from sintered metal end of assembly see figure 3.
4. Trace wires of sensor to be changed to mil spec connector and extract pins from connector. Extractor tool #8000-034 should be utilized for this purpose. Note color of wire and location in pin connector.
5. Remove sensor from plastic sensor block.
6. Mount new sensor in plastic block as follows:

   Combustible - Note which sensor is marked reference and the colors of the wires. Place like sensors and wire colors in same positions (see figure 3).

   Oxygen - Remove from nitrogen bag and snap off shorting clip from sensor. Note wire colors and place like wires in same position.

   Toxic - Remove sensor from bag just prior to use. Note wire colors and place like wires in same position.
7. Push pins into mil connector by applying pressure to metal of pin until it clicks into connector.
8. Mechanically reassemble remote module in reverse order of disassembly.
9. Reconnect to display unit.
10. Calibrate new sensor and check operation of all sensors. New toxic or O_2 cells should be recalibrated after first two hours of operation.

ACCESSORIES

Calibration Kit for hydrogen sulfide COMBO III - #313 - 7710-015
(Includes all gases needed for calibration)

Calibration Kit for carbon monoxide COMBO III - #314 - 7710-001
(Includes all gases needed for calibration)

Remote sensor cable - 20 ft. length - 7710-005

Interference Filter for COMBO III - #314 (10 per pkg.)- 7710-004

Aspirator Attachment with manhole wand - 7710-003

Pin Extractor for removing sensor pins from mil connector - 1603-014

REPLACEMENT PARTS

Oxygen Cell - 5701-001

Combustible Sensor - Matched Pair - 5705-001

Carbon Monoxide Sensor - 5704-001

Hydrogen Sulfide Sensor - 5703-001

Charger - 110 volts AC - 4002-012

Battery Pack - 4002-011

Interference Filters CO Model (pkg. of 10) - 7710-004

Leather Case - 1401-018

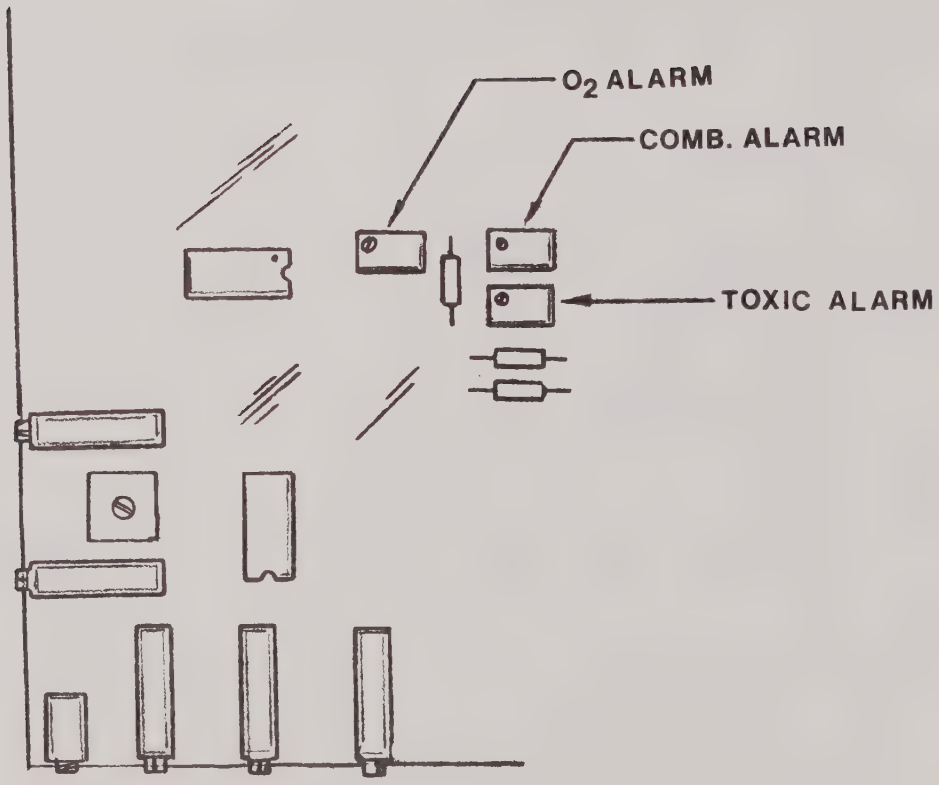
Test Gas - Pure Air - 7800-006

Test Gas - 50% LEL Methane - 7800-011

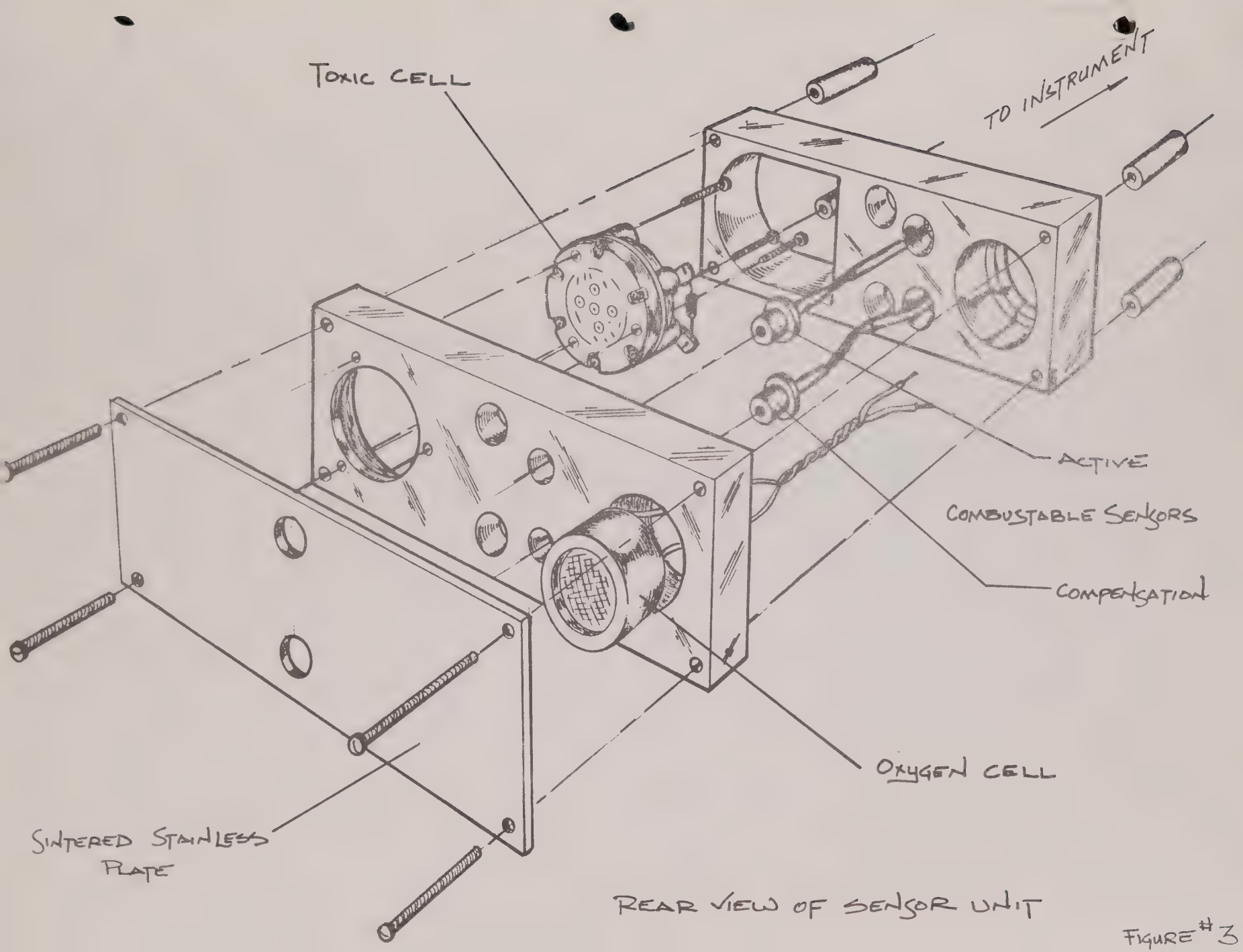
Test Gas - 200 PPM Carbon Monoxide - 7800-004

Test Gas - 20 PPM Hydrogen Sulfide (w/o valve) - 7803-022

Valve for Hydrogen Sulfide Gas Cylinder - 2603-011

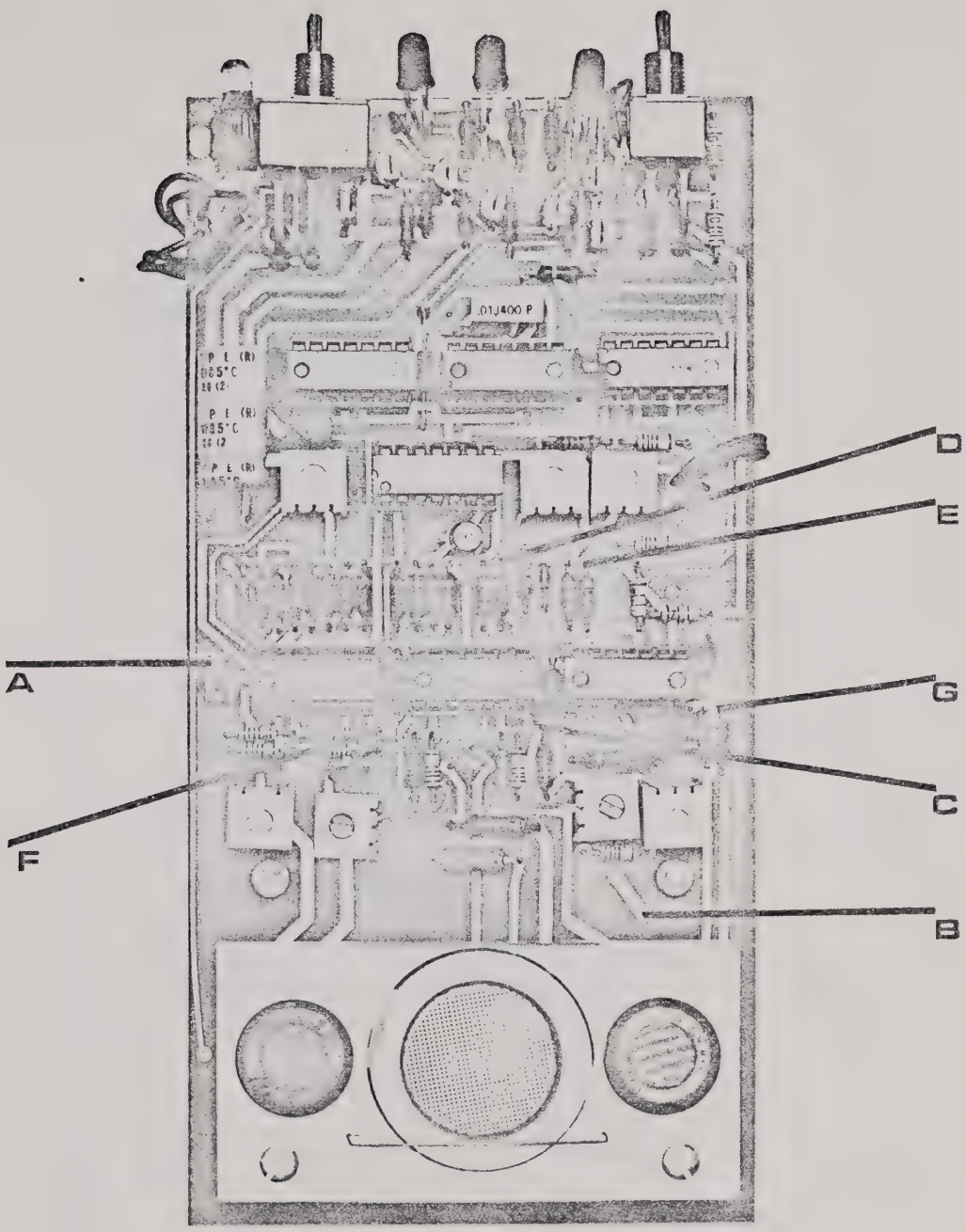


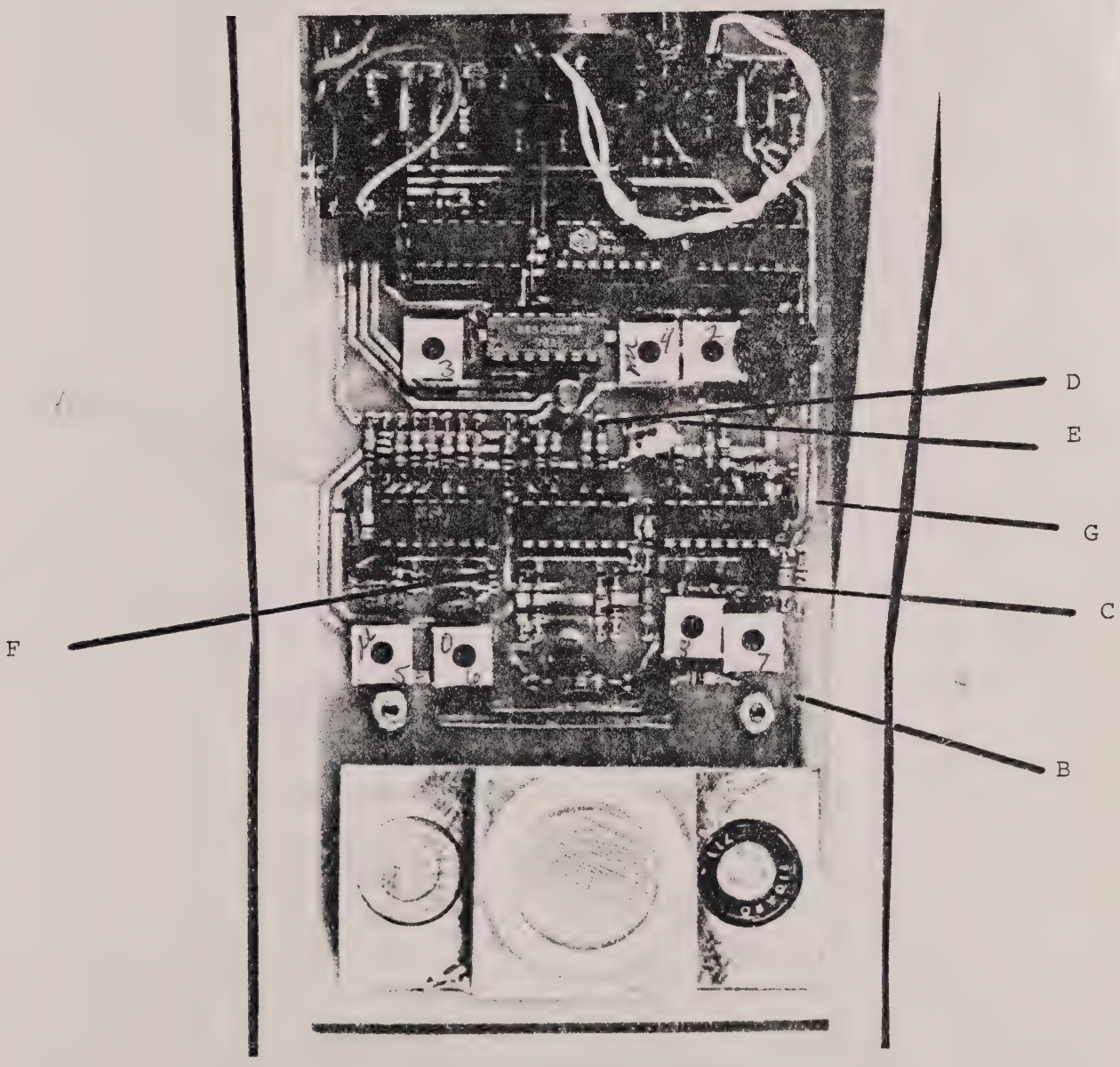
COMBO III ALARM ADJ.
LOCATIONS



REAR VIEW OF SENSOR UNIT

FIGURE #3


A
B
C
D
E
F
G


D
E
G
C
F
B

ESC

dynamation, incorporated p.o. box 2253/ann arbor, michigan 48106/313-769-0573

Dave Menlo
Guc

INSTRUCTION MANUAL

COMBO Model No. 033

CONTENTS

1. General

2. Short Operating Instructions

3. Description

   3.1 External controls
   3.2 Internal controls

4. Principles of Operation

   4.1 Gas sensors
   4.2 Oxygen cell
   4.3 Alarms

5. Operating Instructions

   5.1 Warmup
   5.2 Battery
   5.3 Test
   5.4 Quick operational checks
   5.5 Use

6. Calibration

7. Routine Maintenance

CAUTION: READ MANUAL CAREFULLY BEFORE PUTTING COMBO INTO SERVICE. BE SURE ALL PERSONNEL USING COMBO ARE TRAINED IN ITS OPERATION.

Copyright 1977, Dynamation, Inc.

1. GENERAL

The COMBO will detect and alarm on the presence of combustible, toxic, or low oxygen levels in air. The COMBO is calibrated for the most common underground hazards to alarm at 20% of the lower explosive limit of methane, 10 parts per million (ppm) of hydrogen sulfide, and 19.5% of oxygen by volume. It will detect other combustible and toxic gases as well, such as carbon monoxide in the 200 ppm range.

The COMBO is designed to give years of trouble free service when operated according to instructions. A sealed high impact plastic case with all external controls recessed protects against damage and resists entry of water into the monitor. A silicone rubber coating protects the solid state circuitry. Sensors are plug in replaceable. Careful thermal design provides excellent termperature compensation. Operation is very simple and requires a minimum of training. Fully re-chargeable and exchangeable Nicad batteries give a full eight hours operation so the unit is instantly available for use and can be worn for continuous personal protection.

2. SHORT OPERATING INSTRUCTIONS

1. Switch unit ON. If green light stays off, batteries are low. Recharge batteries.
2. While unit warms up, red and orange lights flash silently. Push TEST switch to check that horn works.
3. When red and orange lights go out, warmup is over and unit is ready to use.
4. Five minutes after warmup push TEST switch to check oxygen cell. Yellow O_2 alarm light and horn should turn on when switch is pushed and turn off when switch is released. If they do not, adjust black O_2 alarm set knob inside the case.
5. If unit stays in alarm too long after removing from gas, switch unit off and on to repeat warmup cycle. If unit stays in alarm too long after removing from low oxygen, push and release TEST switch.
6. After eight hours use recharge batteries or replace battery pack with freshly charged batteries. Green

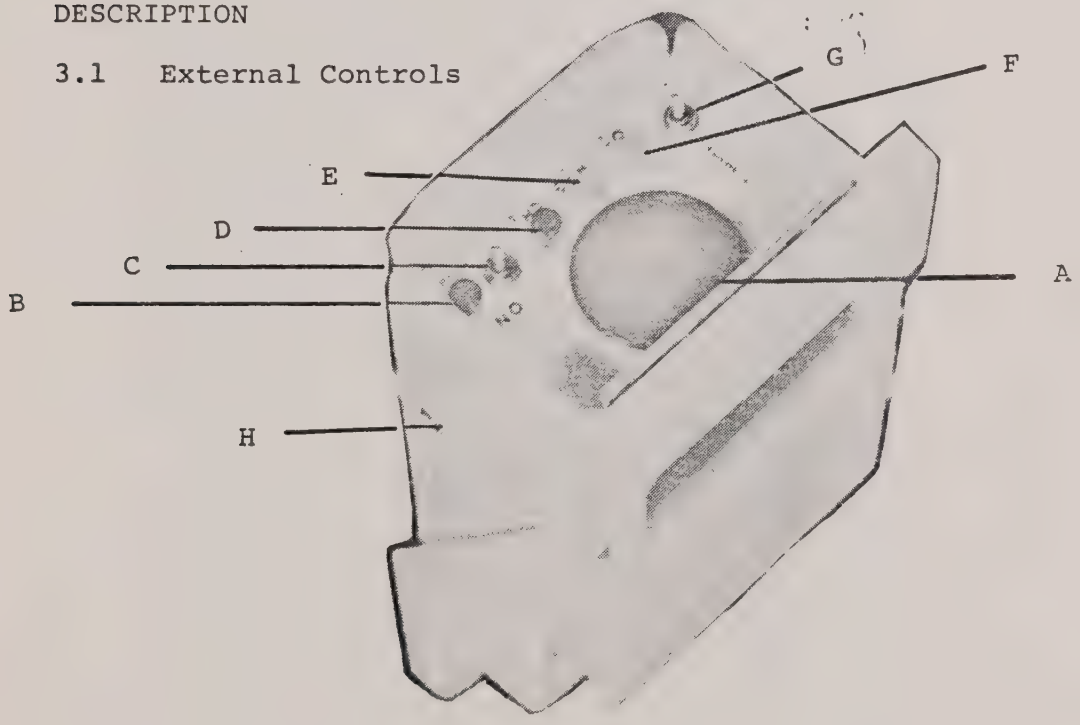
(If unit hasn't been on for a few days, it is advisable to put it through two (2) warmups.)

light will turn off and horn will sound steadily when battery voltage drops too low in use.

CAUTION: ANY INSTRUMENT USED TO PROTECT LIFE MUST BE TESTED FREQUENTLY AND CALIBRATED PERIODICALLY TO INSURE THAT SENSORS ARE WORKING PROPERLY. FOLLOW INSTRUCTIONS FOR QUICK CHECKS AND ALARM POINT CALIBRATION GIVEN IN THE MANUAL.

3. DESCRIPTION

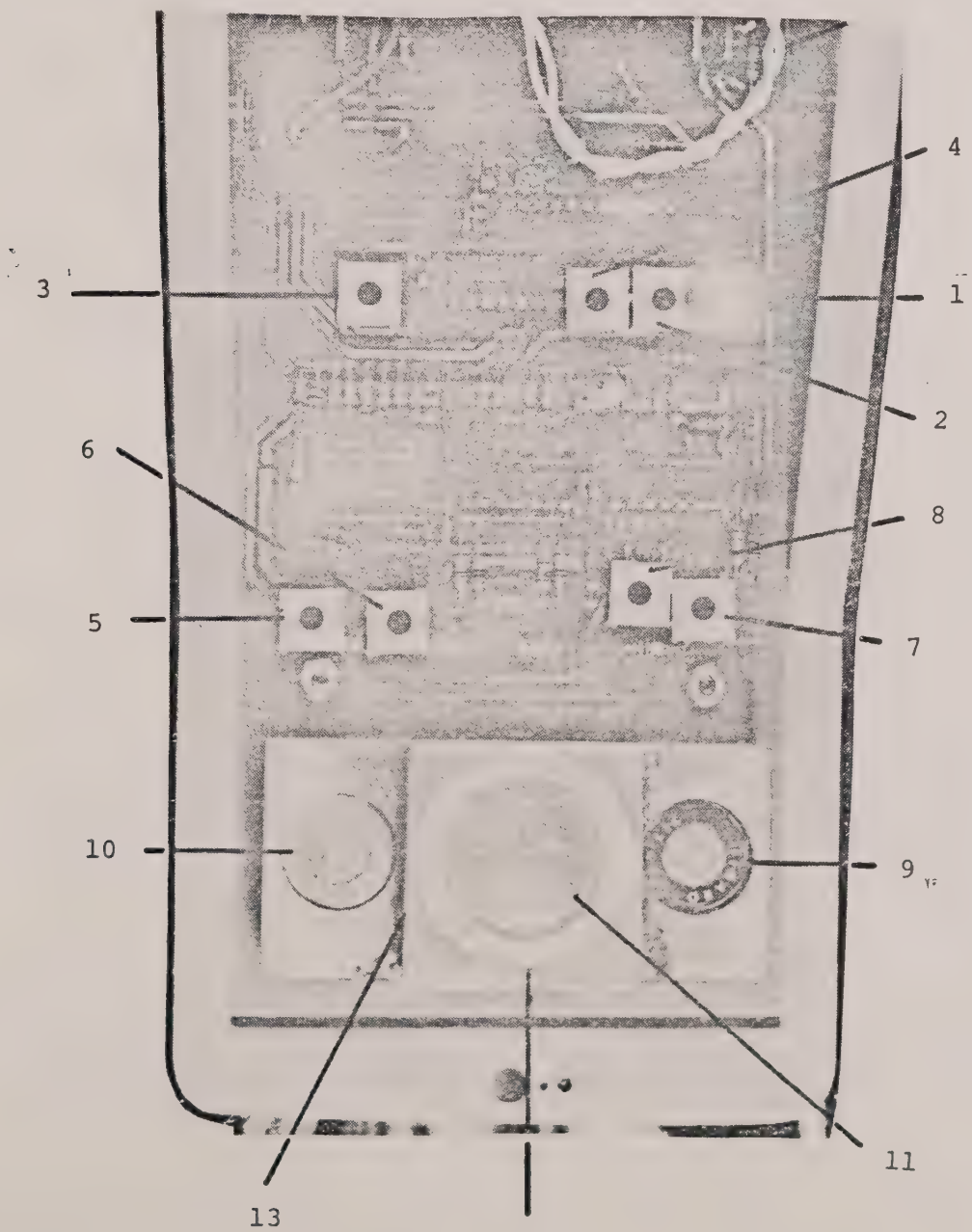
3.1 External Controls



A. Speaker--Produces audible alarm
B. Pilot Light (Green)--Stays on if battery voltage is up
C. ON Switch--Switches unit on and starts warmup cycle
D. Combustible Alarm Light (Red)--Flashes when unit detects methane greater than 20% LEL and in combined alarm
E. Hyrdogen Sulfide Alarm Light (Orange)--Flashes when the unit detects more than 10ppm hydrogen sulfide and in combined alarm
F. Oxygen Deficiency Alarm Light--Turns on when unit exposed to less than 19.5% oxygen
G. Test Switch--Tests speaker operation during warmup and oxygen cell calibration during use.
H. Recharge Jack

F. Oxygen Deficiency Alarm Light - turns on when unit exposed to less than 19.5% oxygen
G. Test Switch - tests speaker operation during warm-up and oxygen cell calibration during use
H. Recharge Jack

1.2 Internal Controls



LEGEND

1. O_2 Alarm Set--Finger adjustable potentiometer to set voltage level at which oxygen deficiency alarm trips
2. H_2S Alarm Set--Screwdriver adjusted potentiometer to set voltage level at which H_2S alarm trips
3. Combined Alarm Set--Screwdriver adjustable potentiometer to set voltage level at which combined alarm trips
4. CH_4 Alarm Set--Screwdriver adjustable potentiometer to set methane alarm trip point
5. Gain Set--Adjusts circuit gain
6. Zero Set--Adjusts clean air circuit voltage level
7. Sensor Heater Set--Adjusts gas sensor operating temperature
8. Balance Set--Adjusts circuit voltage level when gas sensors exposed to gas

9,10. Gas Sensors--Solid state catalytic semiconductor sensors for detecting toxic and combustible gases

11. Oxygen Cell--Electrochemical micro fuel cell which senses oxygen level
12. Aluminum Heat Sink Block--Stabilizes sensor temperature and extend range of oxygen cell
13. Temperature Compensation Thermistor--Senses oxygen cell temperature to compensate for changes in cell temperature

CAUTION: THE FIRST ROW OF CONTROLS 5, 6, 7, AND 8 (GAIN, ZERO, BALANCE AND HEATER) ARE FACTORY SET AND SEALED AND MUST NOT BE ADJUSTED UNLESS GAS SENSORS ARE CHANGED AND CALIBRATED IN ACCORDANCE WITH PROCEDURES IN THE MAINTENANCE MANUAL.

4. PRINCIPLES OF OPERATION

4.1 Catalytic semiconductor sensors are used in the COMBO to detect toxic and combustible. When an oxidizeable gas in air reaches the catalytic surface of the sensor, it

reacts with the oxygen in the air:

$$CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$$

$$2\ H_2S + 3\ O_2 = 2\ SO_2 + 2\ H_2O$$

$$2\ CO + O_2 = 2\ CO_2$$

The reaction taking place at the surface of the semiconductor changes the resistance of the semiconductor material directly, not through the heat generated by the reaction. Therefore, quite low concentrations of some gases can produce large changes in the resistance of the semiconductor material, and the sensor is sensitive down to the parts per million (ppm) range for certain gases. The resistance change is detected by the electronic circuitry and converted to a voltage signal which is used to trip the alarms.

To speed up the rate of the chemical reactions and make the sensor respond faster to the presence of gas, the sensor is operated at an elevated temperature, about 300° F. An electrical heater coil embedded in the sensor heats the sensor up to the operating point. However, the surface temperature of the sensor is below the ignition temperature of combustible gas in air mixtures (unlike conventional hot wire or platinum catalytic gas detectors) so the sensor is intrinsically safe. Flame arrestor screens are used in the sensor case to provide further safety.

Catalytic semiconductor sensors are not completely specific to any one gas; generally any gas which can be oxidized by oxygen will produce some change in the resistance of the semiconductor material. However, by changing the semiconductor catalyst composition and the operating conditions the sensitivity of the sensor to different types of gases can be enhanced. The COMBO uses two different semiconductor sensors. One is sensitive to readily oxidizeable gases such as CO and H_2S and is used for toxic gas detection; the other is sensitive to hydrocarbon gases such as CH_4 (methane) and is used for combustible gas detection. Both sensors are in continuous operation for continuous monitoring of both toxic and combustible hazards.

The resistance of the semiconductor sensors is affected by other variables besides the concentration of the gas: humidity, temperature, and drift with time after the sensors

are turned on. Humidity decreases the sensor resistance, but generally sensor operation is more stable in humid air than in dry air. Ambient air temperature changes can affect the sensor temperature and shift the calibration. Sensor resistance in clean air will increase during the first few hours after turn on and shift the calibration point. Therefore any gas monitor using semiconductor sensors must include some means for compensating for the effects of humidity, temperature, and drift to give reliable readings or alarms.

The response of the two sensors in the COMBO is measured by two separate methods and circuits. The first is a differential method, in which the two sensors are opposed to each other. Since one sensor has a strong response to toxic (H_2S and CO) gases and a weak response to combustible hydrocarbon gases (CH_4), the output of the differential circuit will swing in one direction when the sensor pair is exposed to H_2S and swing in the opposite direction when the sensor pair is exposed to CH_4. Two separate voltage level detection circuits are used to monitor the differential circuit output and trip the separate H_2S and CH_4 alarms, set at low voltage level and a high voltage level respectively. When the sensors are read out in opposition or in a differential mode, the effects of humidity, temperature, and drift are cancelled out since the two sensors both respond similarly to these variables.

The second method for reading out the response of the two sensors is additive, in which the circuit detects the sum of the resistance changes of the two sensors. The purpose of this circuit is to alarm on combinations of gases or on gases in which the two sensor response characteristics are similar. Combinations of gases might not produce enough unbalance of the differential circuit to trip the individual alarms. Since the additive circuit is not compensated for ambient effects on the sensors, the alarm point is not as stable as the alarm points for the differential circuit. Standard setting for the additive alarm point is 10 ppm H_2S and 20% LEL methane in the worst case (dry gas), and about 200 ppm CO. Voltage levels out of the additive circuit for these conditions are high enough to prevent nuisance false alarms for non-hazardous amounts of gases present in combination.

The gas sensors have a lifetime measured in years because of the low temperature of operation. They are highly resistant to poisoning by gases, but can be damaged if the surface gets

coated with a solid or oily film such as might be produced by a heavy exposure to smoke or oil mist. In some cases this film can be oxidized off by sending the sensors through a number of warmup cycles. If this is done the alarm points should be re-calibrated.

4.2 Oxygen Cell.
The oxygen cell used in the COMBO is a disposable electrochemical cell; basically it may be thought of as a battery whose current output depends on the concentration of oxygen reaching one electrode. The oxygen reaches the electrode by diffusion through a thin Teflon membrane covering the top of the cell. The Teflon membrane must be kept clean and undamaged for proper operation of the cell. The basic cell reactions are:

$$\text{Cathode: } 4\ e^- + 2\ H_2O + O_2 = 4\ OH^-$$

$$\text{Anode: } 2\ OH^- + Pb = PbO + H_2O + 2\ e^-$$

The electron (e^-) flow through the external circuit produces the output current proportional to oxygen concentration. A drop in current produced by oxygen deficiency is detected by the circuitry which trips the oxygen deficiency alarm. Since fresh air contains a constant 20.9% O_2, it can be used for calibration checks; the TEST switch on the COMBO performs this function.

The output of the oxygen cell is very stable with time and is not sensitive to shock, vibration, gas flow, position, or interfering gases. The cell output current is sensitive to temperature changes. A special circuit using a precision (1% accuracy) thermistor is used in the COMBO to compensate precisely temperature changes. In order to insure that the thermistor temperature and the cell temperature track precisely during temperature changes, the thermistor and cell are both embedded in an aluminum heat sink. Thermally conducting silicone grease is used to insure good thermal contact between the cell, thermistor, and block. This contact must be maintained when cells are replaced for proper operation.

Normal operating temperatures range of the oxygen cell is 20° F to 125° F. The liquid electrolyte in the cell freezes at about 15° F. To entend the operating range of the cell, the gas sensors were also embedded in the block. Since the

sensors give off heat, the block and O_2 cell are kept 10^o to 20^o F above ambient temperature; therefore the COMBO may be used continuously at ambient temperatures close to 0^o F. The COMBO may be used at much lower temperatures provided that the exposure of the oxygen cell to low temperatures is limited in time, so that the cell does not reach a final temperature below 15^o F.

The nominal lifetime of the oxygen cell is 12 months in air. Since the cell reactions continue whether the instrument is turned on or not, cell lifetime starts when the cell is exposed to air and ends when the electrode material (Pb) is used up. Cell replacement is simple, as they plug into the circuit board. Replacement cells are sealed in nitrogen gas-tight bags and have a shelf life of two years. Cell output normally is quite steady with time until the end of life; when frequent large adjustments of the O_2 alarm set control must be made the cell should be replaced.

4.3 Alarms

There are four adjustable points in the COMBO. H_2S (toxic), CH_4 (combustible) from the differential circuit; O_2 from the oxygen cell circuit; and combined gas from the additive circuit. Voltage level trip points are set by four potentiometers controls, which should be adjusted only when the sensors are exposed to calibration gas following the calibration procedure in Section 6. The low battery alarm is fixed and trips when the battery voltage reaches 5.75 volts.

ALARM	VISUAL	AUDIBLE	ADJUSTMENT (Increase Sensitivity)
Low battery	Green light off	Continuous low tone	None
Methane (Combustible)	Flashing red light	Interrupted low tone	CW(clockwise)
H_2S (Toxic)	Flashing orange light	Interrupted high tone	CCW(counter clockwise)
Oxygen Deficiency	Steady yellow light	Steady high tone	CCW
Combined Gas	Flashing red & orange light	Alternating low & high tone (yodel)	CCW
Warmup	Flashing red & orange light	None	None

5. OPERATING INSTRUCTIONS

5.1 Warmup

When the unit is left off, gases, vapors, and particles can accumulate on the catalytic semiconductor surface. This accumulation must be removed before the sensors will detect gas correctly. During the warmup cycle the sensors run hotter than normal to accelerate cleaning off the sensor surface. Warmup lasts three to four minutes and is indicated by the red and orange lights flashing silently. When warmup is over, the lights go out automatically.

If the COMBO is to be used occassionally during a shift instead of continuously, it is better to leave the unit ON all the time rather than turning it on and off. The warmup cycle is activated each time the unit is turned off and on, even momentarily. By leaving the unit on there is no wait for warmup. Also, since the sensors are running hotter during warmup, there is a short wait (about five minutes) for the aluminum block, oxygen cell, and thermistor temperature to stabilize and the oxygen cell output to reach maximum accuracy. The O_2 cell will detect oxygen deficiency immediately after warmup, but the O_2 test should be done after a five minute wait to let the temperature stabilize.

5.2 Test

The TEST switch has two functions; to test the horn operation and to check O_2 cell calibration. Pushing the momentary TEST switch during warmup will defeat the speaker lockout and cause the speaker to sound if the audible alarm is working properly.

The other function is to switch the output of the O_2 circuit to a voltage divider which reduces the voltage to the desired alarm point (standard 19.5% O_2). The O_2 alarm circuit is designed to trip at 19.5% O_2 and to drop out very close to 20.9% O_2. When the TEST switch is pushed in clean air, the O_2 alarm should go on, and go off when the switch is released. If the O_2 alarm control is set too low, the alarm will not drop out in clean air and will continue to sound when the switch is realeased. If the alarm does not go on when the TEST switch is pushed, open the case by sliding back the latch under the sensor compartment. Push the TEST switch. Adjust the black O_2 alarm set control until the O_2 alarm trips (yellow light, steady tone). Release the TEST switch. If the alarm does not go off, back off the alarm set control until the alarm goes off. Repeat TEST until alarm goes on when the switch is pushed

and off when released.

CAUTION: WHEN THE COMBO CASE IS OPEN TAKE CARE NOT TO DAMAGE THE TEFLON MEMBRANE ON THE TOP OF THE OXYGEN CELL OR GET IT DIRTY. DO NOT TOUCH THE TOP OF THE CELL. DIRT OR FINGERPRINTS WILL REDUCE THE AMOUNT OF OXYGEN GETTING INTO THE CELL AND PRODUCE LOW AND ERRATIC OUTPUTS. DAMAGE TO THE MEMBRANE WILL LET OTHER GASES INTO THE CELL AND RUIN ITS OPERATION. DAMAGE TO THE TOP OF THE CELL WILL VOID WARRANTY.

5.3 Batteries

The COMBO is powered by five Nicad C size cells held in a removable battery pack. A sealed charge jack on the side of the unit connects the charger to the unit. The charger is designed for an overnight (14 to 16 hours) recharge of a fully discharged battery pack; it may be left on for extended periods of time without battery damage. A 12 volt charger adapter is available to plug into an automotive cigarette lighter; the charge rate is the same as the AC charger.

To allow extended periods of continuous operation, the battery pack is removable for exchange with a freshly charged battery pack. To exchange battery packs, open the instrument case. Do not turn the unit off (to avoid waiting for another warmup cycle). Grasp the connector at the battery pack firmly and pull to separate the connector.

CAUTION: DO NOT PULL ON THE WIRES TO SEPARATE THE BATTERY LEAD CONNECTOR. PULL ON THE CONNECTOR BODY ONLY.

Slide the battery pack latch back to free the battery pack. Lift out the low battery pack. Insert the freshly charged pack by placing the tab on the pack under the retaining lip on the case. Push the pack down over the stud and slide the latch forward to retain the pack. Push the battery lead connector plug into the receptacle in the pack until it seats firmly and the locking ears in the plug are engaged in the receptacle. The green pilot light should go on. If this operation is completed in less than two minutes the unit will not go through a warmup cycle and will be completely ready to use within two more minutes after connection of the fresh pack. Place the low battery pack on charge.

In continuous use, low battery voltage is indicated by the low battery alarm. If the battery voltage drops below 5.75 volts, the green pilot light will go cut and a continuous tone audible alarm will sound. The alarm will continue until the batteries drop below circuit operation voltage. Below 5.75 volts, the operation of the gas sensor circuits is unreliable and the unit may possibly go into a false gas alarm or fail to detect gas.

CAUTION: DO NOT USE COMBO AFTER LOW BATTERY ALARM GOES OFF. RECHARGE OR REPLACE BATTERIES.

Under normal conditions the batteries when fully charged should provide about 9 hours continuous operation. (8 hours guaranteed.) However, this assumes that the unit has been used on an eight hour on, sixteen hour recharge cycle. If the COMBO has been used only for a short period of time each day, then recharged, then the batteries may not deliver a full eight hours' operation when required. This effect is characteristic of nickel-cadium batteries. If the unit has been on a short discharge cycle, it should be put through a full discharge--overnight charge cycle before attempting a full eight hour operation. If the unit is used regularly on an eight hour on-sixteen hour charge cycle, this will not be needed.

CAUTION: REPEATED COMPLETE DISCHARGE OF BATTERIES WILL REDUCE BATTERY LIFE. TURN UNIT OFF WHEN LOW BATTERY ALARM GOES OFF AND PLACE ON CHARGE.

Temperature will affect the operating characteristics of any nickel-cadium battery. At extreme temperatures, the battery will not deliver its full rated capacity in ampere hours, according to the following table:

Temp °F	DISCHARGE Nominal % Capacity	Nominal Run Time
0	55	4.95 hours
20	70	6.3
40	90	8.1
60	95	8.55
80	100	9
100	90	8.1
120	70	6.3

The temperatures are the actual cell temperature, not the ambient temperature; capacity is the charge put into the cell; run time in hours assumes that the battery was charged at room temperature. If the battery is charged at a high temperature it will not be charged to its full rated capacity; if both charged and discharged at high temperature available run time will be reduced further. Charging at 115° F will produce a capacity of 80% of room temperature. Charging at low temperatures will give 100% capacity.

	TEMPERATURE LIMITS
CHARGE	32° F to 115°F
*DISCHARGE	-40°F to 140°F
*STORAGE	-40°F to 140°F

*NOTE: OXYGEN CELL WILL BE DAMAGED BELOW 0° F OPERATING, 15° F STORAGE.

All temperatures given are actual battery temperatures. If the COMBO is charged and stored at room temperature and brought into low or high temperatures, considerable time will be required for the batteries to come to the new temperature and run times will be extended accordingly.

5.4 Quick Operational Check

The COMBO should be checked frequently to insure the sensors are working. The checks described below have been found convenient.

NOTE: THE QUICK CHECKS DO NOT INDICATE IF THE ALARM POINTS ARE SET AT THE PROPER GAS LEVELS.

CH_4 (Combustible):

Hold the COMBO in a vertical position. Take a butane lighter, press down the lever but do not light. Pass the lighter back and forth under the lower part in the case. The CH_4 alarm should go on. A heavy shot will require some time for the alarm to clear.

The same test can be done with an unlit natural gas jet or propane torch using a very low flow. Gasoline vapors from a rag or can will usually be heavy enough to trip the combined alarm.

H_2S (Toxic) and Combined:

Puff cigarette smoke (Not inhaled) over the porous plastic filter. One or two generous puffs should set off the H_2S and combined alarms.

The same test can be done with automobile exhaust, if the unit is held out of the direct exhaust stream so the exhaust gas can mix with air before reaching the sensor.

CAUTION: AVOID LONG EXPOSURE TO TOBACCO, EXHAUST OR OTHER SMOKE TO AVOID LOADING THE SENSORS. ALWAYS PERFORM THIS TEST THROUGH THE POROUS PLASTIC SCREEN.

O_2 (Oxygen Deficiency):

Hold the COMBO close to the mouth. Exhale deeply and slowly over the porous plastic. The O_2 alarm should go on. Do not blow directly on the screen, since this could cool one gas sensor more than the other and trigger a gas alarm.

If alarms fail to operate, check the following before troubleshooting or calibrating unit:

1. Battery voltage is up--green light is on.
2. Porous plastic filter is not clogged.
3 O_2 cell gives proper alarm when TEST switch pushed

5.5 Use

After warmup and test the COMBO is ready to use. Although on-off operation if done according to instructions will not affect instrument accuracy, continuous operation is more convenient and involves less waiting time. The COMBO may be worn on the person, lowered into the manhole, or the air in the manhole sampled with the aspirator attachment. The porous plastic filter will let air through but keep dirt and water out for all methods of sampling.

CAUTION: IF THE AIR IS SAMPLED AT THE ENTRANCE OF A MANHOLE OR ENCLOSURE THE COMBO SHOULD BE WORN OR CARRIED IN TO GUARD AGAINST POCKETS OR LAYERS OF HAZARDOUS GAS WHICH DO NOT REACH THE ENTRANCE.

If the unit is exposed to a heavy concentration of hydrogen sulfide it may take quite some time to clear and come out of alarm when removed to clean air. If this happens, put the unit through a warmup cycle by turning the unit off and on; the unit will be ready to use after warmup.

If the unit is exposed to low oxygen air it may take some time to come out of O_2 alarm since the dropout point is close to 20.9% O_2. If this happens, push the TEST switch to drop out the O_2 alarm.

When sampling, be sure to allow sufficient time for the instrument to come to a stable reading before withdrawing or stopping sampling. In normal diffusion sampling without an aspirator enough time must be allowed for the air in the sensor compartment to exchange with the outside air, as well as the response time of the sensors themselves. Aspiration flushes out the sensor compartment and therefore takes less time.

CAUTION: WHEN LOWERING THE COMBO INTO A MANHOLE OR ENCLOSURE WAIT AT LEAST TWO MINUTES FOR AN ALARM BEFORE CONCLUDING THE AIR IS SAFE. LOWER ALL THE WAY TO THE BOTTOM.

Because many hazardous gases, such as CO_2 which produces oxygen deficiency, are heavier than air they may lie in layers close to the ground. If operations require bending over or kneeling, check the air near the ground with the COMBO before proceeding.

Natural ventilation is not very efficient in clearing gases out of manholes and tunnels. Even if the manhole has been left open for some time, do not assume that it has been ventilated. Check the air with the COMBO. If a hazard has been detected, it is much safer to use positive ventilation from an efficient blower system than to depend on natural ventilation.

After eight hours use, or when the low battery alarm goes off, turn the COMBO off and plug into the battery charger, or replace the battery pack according to the instructions in section 5.3. Preferably recharge the unit near room temperature to get full charge capacity.

CAUTION: DO NOT STORE THE COMBO AT TEMPERATURES BELOW FREEZING TO AVOID POSSIBLE DAMAGE TO THE OXYGEN CELL. DO NOT STORE ABOVE 120° F.

Keep the case closed to avoid contamination except when calibrating or setting the oxygen alarm.

If the O_2 alarm point keeps drifting rapidly from day to day the oxygen cell is coming to the end of its lifetime. Change the oxygen cell according to the instructions in section 7.

6. CALIBRATION

ANY INSTRUMENT USED TO PROTECT LIFE MUST BE CALIBRATED PERIODICALLY TO INSURE THAT THE ALARM POINTS OR METER READINGS ARE CORRECT.

The COMBO has been designed to have very good stability. However, no matter how stable an instrument is, it must be calibrated periodically to insure that it is reading correctly. Dynamation recommends a maximum 30 day interval between calibrations.

To calibrate the COMBO, turn the unit on, allow it to go through the warmup cycle, and wait 30 minutes to make sure that the unit is completely stabilized. Place the Dynamation calibration chamber (#75-311) over the aluminum block enclosing the sensors. Be careful not to disturb the thermistor leads at the side of the block. Connect the 75-311 calibration chamber, or equivalent chamber, to a source of calibration gas containing 20% LEL (1% by volume) of methane (CH_4). Start a very low flow of gas through the calibration chamber.

CAUTION: BLOWING THE GAS THROUGH THE CHAMBER AT A FAST RATE WILL CAUSE DIFFERENTIAL COOLING OF THE SENSORS AND WILL GIVE FALSE READINGS.

Wait about two minutes or so to allow the calibration gas to flush the air out of the calibration chamber. If the alarm does not trigger adjust the CH_4 (combustible) alarm, set control slowly with a small screwdriver until the CH_4 alarm triggers. If the alarm triggers very early, back off on the CH_4 alarm set until the alarm stops, then adjust the CH_4 alarm set control until the alarm triggers.

Dynamation's standard CH_4 calibration gas contains low oxygen so the operation of both the CH_4 and oxygen alarms can be

checked. Users of a number of COMBO units may find it more convenient to purchase large cylinders from a speciality gas supplier. When specifying standard gas, the following conditions should be kept in mind:

1. Gases must be mixed in air (not nitrogen or other carrier gas lacking oxygen).
2. Oxygen concentration should be specified. O_2 down to 19% by volume will not affect combustible alarm points significantly, but if O_2 alarm is set much below 19% O_2 oxygen and gas alarms should be checked separately, not simultaneously.
3. Some balance air mixtures are blended with nitrogen and electrolytically generated oxygen. If not treated for hydrogen removal, these mixtures can contain several hundred ppm of hydrogen, which could produce errors in the H_2S (toxic) gas calibration.
4. Contact Dynamation for specifications on H_2S equivalent gas.

Hydrogen sulfide calibration can be checked with Dynamation's hydrogen sulfide equivalent calibration gas, using the above procedure. Mixtures of H_2S in air are not stable over a period of time. Dynamation factory calibrates the COMBO with a permeation tube system which generates a constant ppm of H_2S in a flow system. Users of a number of COMBO units may find it more economical to calibrate on H_2S using a permeation tube system; contact the factory for recommendations for manufacturers of permeation tube systems.

The combined alarm set control is factory calibrated by flowing a methane in air mixture through the H_2S permeation tube system. Satisfactory field calibration checks of the combined alarm can be done by flowing a humidified sample of 200 ppm carbon monoxide (CO) in air through the calibration chamber.

Oxygen alarm calibration normally is satisfactorily set using the TEST switch. Once the O_2 alarm set control has been set using the TEST switch, it may be checked by flowing standard CH_4 - 19% oxygen mixture through the calibration chamber.

7. ROUTINE MAINTENANCE

The major item of routine maintenance in the COMBO unit is replacement of the O_2 cell. When the O_2 cell is worn out (as detected by symptoms described in preceding sections) turn the unit off. Open the case.
Carefully remove the thermistor from the hole in the aluminum heat sink block.

CAUTION: THERMISTOR LEADS ARE FRAGILE. AVOID FLEXING MORE THAN NECESSARY. HANDLE GENTLY.

Lift the aluminum block off the sensors and oxygen cell. Unplug the old oxygen cell and discard. Cut open the sealed bag containing the replacement cell and remove the shorting clip from the cell. Plug the new cell into the circuit board. Replace the aluminum heat sink block over the sensors and cell and press down gently until the tops of the sensors and the oxygen cell are flush with the top of the aluminum block. Insert the thermistor bead into the hole in the block , making sure that there is white silicone heat transfer compound on the bead. Push the bead into the hole until it makes contact with the cell and place the leads into the groove in the block. Close case and switch unit on. After warmup and a five minute wait, test O_2 alarm with TEST switch. The O_2 alarm will usually have to be reset when the cell is changed.

CAUTION: NEVER TOUCH THE TOP OF THE OXYGEN CELL (GOLD GRID). HANDLE ONLY BY THE SIDES OR THE WHITE PLASTIC RIM ON THE TOP. DO NOT LET THE HEAT TRANSFER COMPOUND GET ON THE TOP OF THE CELL. DAMAGE TO THE MEMBRANE ON TOP OF THE CELL WILL RUIN THE CELL AND VOID WARRANTY.

Contamination on top of the oxygen cell will prevent oxygen from getting into the cell and will cause low readings. Water soluble contaminants can be removed by rinsing the top of the cell (after removal from the unit) with distilled water. Greasy contaminants (including fingerprints) will permanently reduce the cell output and possibly cause erratic readings.

The semiconductor sensors, if not contaminated, have a long life and should not have to be replaced. Matched pairs of sensors are required. If the facilities of an instrument repair shop are not available, it is recommended that the unit be returned to the factory for sensor replacement. If adequate facilities

are available, refer to the Maintenance Manual for setup and calibration instructions for new sensors.

The porous plastic filter over the parts in the sensor compartment may become clogged with time. If the plastic shows resistance to blowing or sucking air through it, or appears dirty, clogged, or broken, it should be replaced. Push on the filter through the smaller (bottom) slot in the sensor compartment until the edge of the filter clears the aluminum retaining strip. Pull the old filter loose. Insert the new filter under the plastic ledge at the back of the sensor compartment and snap the short edge under the plastic strip. Press the plastic in until it seats against the inside of the cover.

The speaker assembly is protected by a piece of the same porous plastic material used for the sensor compartment. If the speaker or plastic should become damaged, open the case. Unsolder the speaker leads. Press the speaker mounting bushing out of the hole in the case. Press in a replacement speaker. Resolder the leads. Switch unit on and press TEST switch for test of speaker operation.

For troubleshooting and replacement instructions for components on the circuit board, refer to the Maintenance Manual.

dynamation

dynamation, incorporated p.o. box 2253/ann arbor, michigan 48106/313-769-0573

COMBO - H_2S Test

General

Because H_2S is unstable and corrossive, it is impossible to package 10ppm H_2S and air in a test cylinder. However, a higher concentration mixed in nitrogen can have a shelf life of three months in a cylinder. The COMBO H_2S alarm can be tested by mixing the higher concentration nitrogen base test gas (77-500C) with air in the calibration cup.

Equipment

The equipment needed to test the COMBO is the calibration kit 76-311 and 77-500C test gas.

Test Procedure

1. Turn instrument on for ½ hour before testing.

2. Remove the vinyl tube at the calibration cup's connector.

3. Place the test tank valve and tubing on the hydrogen sulfide gas cylinder - 77-500C.

4. Insert the 20cc syringe into the vinyl tubing and open the gas valve until the syringe has 10cc. Insert the 10cc into the calibration cup at the tube fitting. Refill the syringe with 15cc of H_2S test gas and insert it into the calibration cup.

5. Wait 30 seconds and if the H_2S light hasn't alarmed, rotate H_2S alarm pot 2 to trigger the alarm light.

6. Remove the calibration cup from the unit and disconnect the valve from the tank.

dynamation

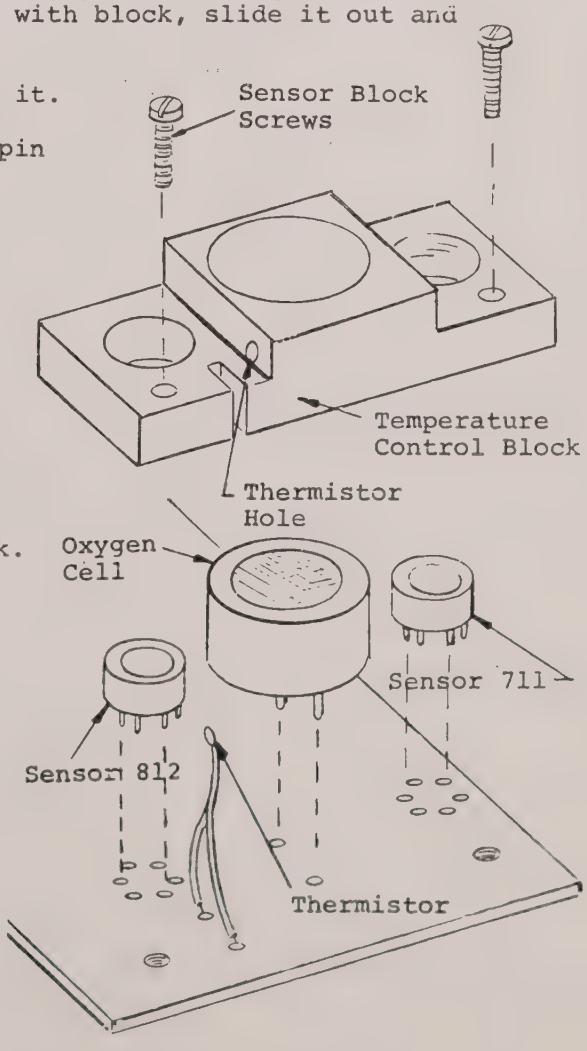
dynamation, incorporated p.o. box 2253/ann arbor, michigan 48106/313-769-0573

INSTRUCTIONS FOR CHANGING O_2 CELL

General

Complete care and maintenance of the oxygen cell is given in the instruments instruction manuals. The life of the cell is normally one year. Some cells will last more than six months, while other may last more than a year. The reason for the close fit between the sensors and the block is to heat the O_2 cell and provide temperature compensation. Do not push or place fingers on the gold colored grid on top of the cell.

1. Keep cell in nitrogen filled bag until ready to use.
2. Cut open the bag and remove the metal shorting clip.
3. Carefully remove the thermistor wires from the block (see sketch).
4. Remove screws, lift block off sensors by pulling up equally on both ends -- should sensors come out with block, slide it out and replug it.
5. Remove the oxygen cell by unplugging it.
6. Replace O_2 cell by locating outside pin toward bottom of unit.
7. Locate block over sensors with slot toward bottom. Carefully slip block over three sensors.
   a. if O_2 cell is not aligned, rotate 180°.
   b. if O_2 cell does not fit, remove label around it and cut two small pieces to cover the two wires in the side to prevent a short in cell.
8. Carefully replace thermistor in block.
9. Turn unit on and give the cell 10 minutes of operation before setting the O_2 alarm with the test and O_2 alarm pots.



Accesory and Replacement Parts

ITEM	NUMBER
Calibration kit(for use with portable cylinders of calibration gas) includes chamber, valve, and tubing	75-311
Calibration chamber only	75-312
Portable gas cylinder valve only	75-313
Oxygen cell	76-801
Matched sensor pair	76-711
Porous plastic screen (package of ten)	76-410
Speaker assembly	76-501
Battery pack assembly	76-333
110 VAC charger for unit	76-334
110 VAC charger for spare battery pack	76-335
12 V DC automobile cigarette lighter charger for unit	76-336
Aspirator attachment (includes aspirator bulb, case attachment and tubing)	75-310

dynamation

dynamation, incorporated p.o. box 2253/ann arbor, michigan 48106/313-769-0573

COMBO Model 034 - TEST VOLTAGES & TROUBLE SHOOTING

All voltages given are after the unit has been through warm-up and 15 minutes of operation. These voltages are all positive voltages to battery ground.

Open Batt

Test Point A - Battery voltage between plus and ground side should be a minimum of 6.0 volts.

Heat

Test Point B - Heater voltage with the unit not in warm-up should be about 5.0 volts. Pot 7 sets the heater voltage. This voltage will be higher during warm-up.

Test Point C - Test point C indicates the differential voltage of the two semiconductor sensors. The voltage at point C should be between 1 and 1.7 volts while the sensors are in clean air.

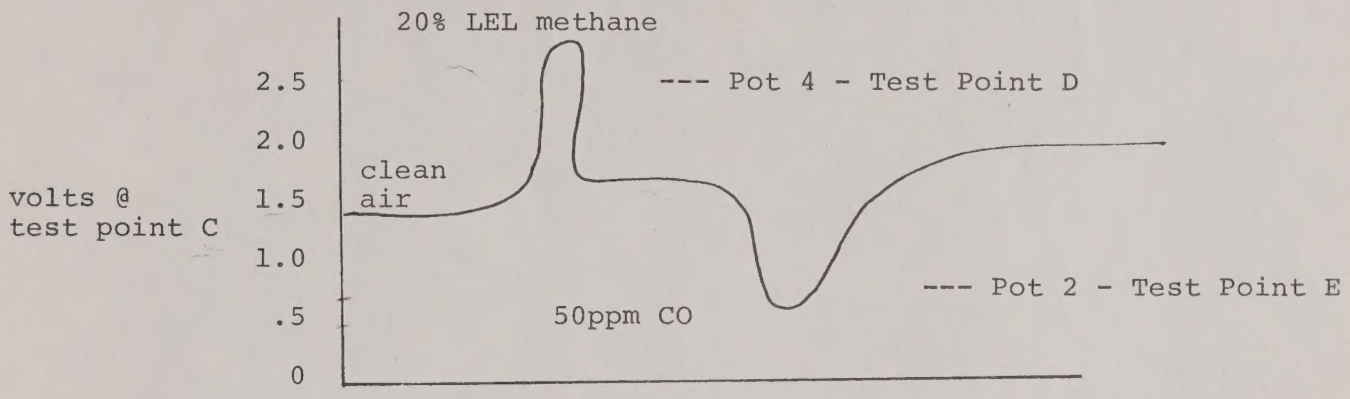
When methane or combustible gas is applied to the sensors, the differential voltage at C should swing to a higher voltage value. If 20% LEL methane is applied to the sensors, the voltage should be in the 2-3 volt range. If the combustible gas alarm (4) is set to alarm with 20% LEL on the sensors, it is recommended that the combustible alarm pot 4 be rotated so that the alarm triggers at least at .2 volts below the differential voltage of C.

Test Point D - The voltage at which the methane alarm will trigger can be measured at D. Whenever C voltages exceed the voltage of D, the unit will alarm combustible. The voltage of D should vary from approximately 1.2 to 2.5 volts by rotating pot 4. If the 20% LEL methane voltage of C is 2.4 volts, then pot 4 should be rotated until the alarm triggers and the voltage at D is 2.2 volts. Note that pot 4 can not be set to a higher methane voltage than 2.5 for safety reasons and it is acceptable if the methane voltage at C goes to 3 volts.

Test Point E - The voltage at which the carbon monoxide alarm will trigger can be measured at E. If 50ppm CO gas is placed on the sensors, the voltage at C will decrease to a value of .1 to .8 volts.

The carbon monoxide alarm pot 2 should be set at 0.1 volts above the C voltage. For example, if C voltage for 50ppm CO is 0.5 volts, the voltage at E should be set with pot 2 at 0.6 volts. Never set the alarm voltage of pot 2 less than 0.1 volts.

If test point C was recorded we would have the following presentation for methane and carbon monoxide gases:



Test Point F - Test Point F is the voltage of the combined sensors circuit. Its clean air voltage should read about 1 volt. When a combination of 20% LEL methane and 50ppm CO or just 200 ppm CO is applied to the sensors, the combined voltage F will increase to above 2.75 volts. The combination alarm pot 3 is turned to alarm at the highest gas level. Always moisturize the test gas when setting the combination alarm.

Test Point G - With the oxygen cell in 20.9% O_2, the voltage at G should be between 1.0 and 1.7 volts. With less oxygen on the cell, this voltage should drop.

ACCOPRESS®

25970	YELLOW
25971	BLACK
25972	LIGHT BLUE
25973	DARK BLUE
25974	LIGHT GRAY
25975	LIGHT GREEN
25976	DARK GREEN
25977	TANGERINE
25978	RED
25979	EXECUTIVE RED

GENUINE PRESSBOARD

ACCO USA, INC.
770 S. ACCO PLAZA
WHEELING, IL 60090

85072